BASIC AERODYNAMICS

The forces that affect a parachute are invisible, but not incomprehensible. Learn what makes a parachute fly well and you will know what makes it fly badly.
There are two basic ways for parachutes to slow our descent - lift and drag. A round parachute creates drag by simply grabbing as much air as it can, putting on the brakes for us. But a square parachute creates lift, which forces an air foil in a particular direction determined by the design of the foil and its presentation to the fluid it moves in. Controlling the flow of air over the foil is the art of the canopy pilot.

Lift

A canopy produces lift in two ways. The form of the wing itself produces some lift. Wings are shaped so that air must flow faster over the top of the wing than the bottom. When the velocity of air increases, its pressure decreases. This creates a low pressure area on the top of the wing, and a corresponding higher pressure below. Thus the wing is "lifted" towards the low pressure area.

Deflection of air is the second type of lift. If air is deflected one way, there must be an equal reaction in the opposite direction - the same principle that lets us turn, track, and perform other freefall manoeuvres. The balance of deflection and form lift is a complex one. If deflection were the principle source of lift, in a right toggle turn (the right trailing edge pulled down) air deflected downward would push the right side of the canopy up, putting the canopy in a bank to the left and creating a left turn. But in fact, pulling the right toggle down reduces lift, because it increases drag on that side. With the right side moving slower, it creates less lift. The canopy banks to the right.

The main skydiving use of deflection is at flare time. When a canopy is flared, some air is deflected downward with a resultant upward motion of the canopy. But this also increases drag, slowing the canopy’s forward speed. The pilot beneath, having more mass and less drag, does not slow down as fast and swings forward. This changes the entire angle of attack of the canopy, greatly increasing deflection of air as long as any airspeed remains. We’ll look more closely at this use of deflection when we discuss angle of attack, and in the chapters on practical flying techniques.

Drag

The other main force acting on a canopy is drag. Drag also has two manifestations, which I will call form drag and parasite drag. Put simply, form drag is the result of friction between the air flow and the wing. It is a penalty all wings incur to some extent and you can even think of it is as lift - towards the back! Parasite drag is the result of disruptions of the air flow from irregularities in the wing. The cell openings create turbulence. Seams, packing tabs, lines and line attachment points, the pilot chute, the slider, and even you, the pilot, contribute drag but no lift. Parachutes have never been very effective wings in comparison with airplanes because their very structure creates a great amount of parasite drag.

Lift and drag, then, are both results of airflow over a wing. Because it is the flow of air over the wing that creates these flight forces, more flow means more force. Lift and drag increase in geometric proportion to speed: twice the speed, four times the lift - and the same for drag. This means that airspeed is crucial to performance. Going faster means - to a point - more lift and crisper control response. It also means drag goes up, which is why fast canopies have several design features to reduce drag such as removable pilot chutes, collapsible sliders, and small diameter lines.

Flow Separation

Fluids flowing over a foil have another interesting characteristic - one you can easily see by watching water pass over a rock in a stream. The fluid will try to follow the curves of an object in the smoothest possible path. A foil can have its shape changed to some extent without disrupting the flow. The direction of flow can also change slightly without disruption, but if either the direction of flow or the shape of the foil changes too rapidly, "flow separation" occurs. Instead of cleanly following the shape of the foil, the fluid breaks loose in eddies and ripples. This is very important to canopy pilots because in essence it means that any sudden, radical manoeuvre greatly reduces the lifting efficiency of the foil by reducing form lift. The most common and dramatic example of flow separation for parachutes is a slow speed stall, but as we will see in later chapters, there are many more subtle variations: excessive front riser input, "pumping" the toggles, and extreme toggle input.

Thrust and Weight

For a wing to move through the air and produce lift, there must be some force propelling it. Normally this is called thrust. In an airplane it is easy to understand - the engine does the work. With a sport parachute gravity is the engine. On a ram air parachute, the A (leading edge) lines are shorter than the D (trailing edge) lines, causing the canopy to have a downward tilt. Air is deflected towards the back of the wing, causing forward speed. The weight of the system (you, plus the gear) pulls down on the wing. The wing is sliding, like a sled on a hill, down a slope determined by the trim of the suspension lines.

The more the weight pulls down, the more thrust you get. We commonly refer to the relative amount of weight under a wing as "wing loading," an important term to canopy pilots. In America parachute loadings are based on exit weight - the combined weight of the jumper and all equipment - and expressed as a ratio of pounds per square foot of canopy. This can lead a pilot into the assumption that wing loading remains constant, and in straight and level flight this is true.

However, wing loading can change dramatically during a turn. To illustrate the concept simply think of a weight swung on the end of a string. The faster it goes, the heavier it seems. You have the same effect on your canopy in a toggle turn. As the canopy turns, the pilot's body continues in a straight line until the canopy pulls him to the new heading. If the turn continues, centrifugal force continues to keep the pilot swung out from under the canopy. When the turn stops, the suspended weight then swings back under the canopy. This transition from the "swung out" position to back under the canopy is the moment when the greatest speed is reached. The canopy reaches top speed because of an increase in wing loading as well as the speed garnered from an increase in descent rate.
The faster you turn the more weight appears to be under the canopy. We can think of this as apparent or induced weight, as opposed to simple

suspended weight.

Note that in some manoeuvres you can actually reduce wing loading for a moment. On many canopies the pilot can create a turn that flings his body up while the canopy turns down and for a moment the lines will actually get a little slack - meaning the wing loading has decreased to almost nothing for that point in time.

Up to a point, more weight (thrust) under a parachute enhances performance. Thinking back to our sled analogy, adding weight to the sled will make it go faster up to the point where it begins to sink into the snow or break up. Without sufficient wing loading canopies become sluggish, while increasing the wing loading enhances speed. Since lift increases with the square of the speed, a wing going thirty miles per hour produces four times the lift of one going fifteen miles per hour. That's why a jet airplane can be supported by wings tiny in proportion to a Cessna's, and why people with the proper training can jump relatively small canopies loaded to 1.4 or higher - some are experimenting with wing loadings of 2 or more! The enhanced performance that comes with high wing loading is not only experienced in straight ahead speed, but in turn rate, flare, and overall responsiveness. But everything has its price. The price of high wing loading is seen later, when we discuss flying in the real skydiving environment.

Centre of Mass, Centre of Lift

The centre of lift is a point on the wing where the lift can be thought of as concentrated. The centre of mass is where the weight of the system is focused. On a sport parachute the weight is clearly centred well below the wing, in the form of the pilot. By changing the relative position of the centre of mass to the centre of lift, the pitch of the canopy can be affected, changing the angle of attack.

Angle of Attack

Many skydivers think angle of attack means the angle of the parachute relative to the ground. Not at all! Angle of attack is the angle of the chord line to the apparent wind. Changing the angle of attack is done by applying leverage against the wing. An aircraft does this with its tail section but parachutes lack this capability. Flaring is the only way to make a change in a canopy’s angle of attack. In a flare, as brakes are applied the weight suspended under the canopy (that’s you, the pilot) swings forward because the light, high drag parachute slows down faster than the heavy, low drag pilot. The result is that the angle of attack temporarily increases, generating more lift through greater deflection of air.

Note that in a flare, the changed angle of attack is due to an actual change in the apparent wind felt by the canopy as the weight below it swings forward - a lever action against the wing just like a hang glider flare. Toggle action changing the shape of the canopy does make a contribution, but if the weight swing does not occur the angle of attack does not change significantly and only a little additional lift is produced by the increased camber of the canopy. A deep brakes accuracy approach is the typical example of a landing using brakes but not a flare. In a good flare, a steady application of brakes causes the canopy to go slower and slower; the pilot remains slightly ahead of the normal position under the canopy, retaining the increased angle of attack and increased deflection of air. Once all of the canopy’s speed is used up, the pilot swings back to normal position. At that point there is no speed left to produce lift of either type, and a high rate of descent begins until the canopy regains speed or the ground interrupts the flight.

You may have noticed I use the term "apparent wind" instead of the frequently heard "relative wind." Apparent wind is a common term in sailing. It refers to the wind the sail feels as it passes through the air. The operator often forgets the apparent wind, confused by familiar but useless references such as the horizon. But the foil knows no horizon, only apparent wind. To visualize this principle clearly, think of a drag plane. People who see this formation for the first time often wonder why the bottom canopy stays inflated. But the apparent wind that the canopy feels is much the same as in normal flight. Just because it is upside down doesn't mean it won't pressurize and produce lift - it just means the lift is down.

Angle of Incidence

Now let’s look at angle of incidence, often mistaken for angle of attack. The angle of incidence can be thought of as the trim (nose up or nose down) of the canopy and is built into the parachute by the length of the suspension lines. It can be altered by using either front or rear riser input. Pulling down front risers changes the angle of incidence, not the angle of attack. At the steeper angle, the canopy will descend faster but the apparent wind striking the foil remains fairly constant, although it will shift momentarily as the manoeuvre begins and ends. With most canopies, the trim of the suspension lines results in a tilt where the canopy slides about three feet forward for every one it slides down - a 3 to 1 glide ratio. Flatter trim will let a canopy fly further, but the penalty is that the canopy is not pressurized as well as a more steeply trimmed canopy, resulting in a foil more vulnerable to turbulence. Steeper trim increases descent rate and pressurization but sacrifices glide, and some flare capability is lost.

Camber

When you pull the toggles down, you change not only the angle of attack, but the shape of the wing itself. Camber refers to the amount of curve across the top of the wing. Wings with a lot of camber generate a lot of lift at slow speeds but create a lot of form drag. If you pull the brakes down and hold them steady, this change in camber will affect how your parachute flies. The descent rate will decrease. So will the forward speed. Modern canopies generally get so much of their flare from angle of attack that your best flare will be from full glide. The high descent speed translates into lift when the canopy is flared. But in situations where you want to slow your descent for an extended period, increasing the wing camber by applying brakes is a very effective way to accomplish this.

Summary

Take a minute some day to watch rocks in a fast moving stream. The smooth, round rocks will have a clear layer of water flowing over them with very little turbulence until the water reaches the down stream side of the rock. That smooth flow over the rock is like the lifting air over the top of your canopy. The turbulent water behind the rock is form drag, the wake your canopy leaves behind as it cleaves through the air. Moss, irregularities in the surface, and roughness at the upstream edge is parasite drag - you can see it. Now look at a jagged rock. Flow separation is written all over it, all rough water and no smooth layer. No smooth flow, no lift. No lift, no control.

As you drive down the highway, put your hand out of the window. Find neutral. Angle it up, angle it down... deflection.
How do these abstract ideas about fluids and foil apply to the day to day skydive? We’ll look at that soon. But before we do, let’s take a look at the different canopy designs on the drop zone so we can understand why they are built the way they are, and what we can expect them to do.