Paraglider physics Why We fly the way we do!

There has been much discussion lately about the dangers associated with flying faster, higher performance paragliders. It leaves many of us asking if we have pushed it to far in the quest for increased performance. During top level competitions, with experienced pilots, there has been an abnormally high number of reserve deployments on DHV 3 wings. More recently, there has been a growing trend for pilots to move to DHV 2 or 1-2 wings. Many pilots have felt the demands of controlling an intermediate wing far exceed the performance gains they experience. Several pilots have recently traded in their older higher performance gliders for newer DHV 1-2 or 2 wings and found little loss of performance and found it significantly easier to keep their wings overhead, and inflated.

Many of the newer DHV 1-2 wings have performance levels higher than the intermediate wings of even a couple years ago. Because of their unique performance improvements they need to be flown differently and require the pilot to anticipate the movements of the glider. One thing I have noticed since taking up the sport of paragliding is that there is a definite lack of understanding of some fundamental theory of flight on the part of many pilots. Quite a few pilots it seems take a lot of information for granted, without even investigating the source; a potentially serious oversight given the risks involved. There is nothing complicated about the physics of flight, and it is my hope through a series of articles to enhance your knowledge, and hence improve your decision making process, and give you the knowledge that will make you a better and safer pilot. If you have been flying an older wing and are considering a newer glider, or if you have recently stepped up to a higher performance wing this series of articles will definitely help you achieve the true potential of your aircraft.

In order to evaluate the performance of any glider we need to have a solid understanding of the factors that affect lift and drag, the aspect ratio, and polar curve of the wing. In order to clarify how these items affect our performance we need to review a few basic terms.

Lift is that wonderful thing that keeps us airborne. For the purposes of this discussion will consider lift to be the aerodynamic component that supports our weight in flight. In a later article we will discuss how we can manipulate the controls of our aircraft to exploit the wing to our maximum advantage. For now we need to review a few simple facts. If you look at most airfoils in general use today, you will observe that they have a basically flat bottom, and a curved upper surface. From your first flight you were told that the wing generated lift because the air flowing over your wing separated as it hit the leading edge, with some air passing over the top, and the remainder passing under the bottom and then rejoining at the trailing edge of your wing. Since the air had a greater distance to travel on top of your wing, the pressure was reduced on top of the wing as a result. This difference in pressure causes the wing to be sucked upwards and is defined as lift. Some of you may have been told that the wing deflected the air downwards, much like the way a water-skier stays on top of a lake, and this is how lift was produced. Essentially both statements are correct, but the majority of the lift is caused by the

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pressure differential across the top and bottom of the wing.

Want proof? Conduct a simple experiment. Take a stiff piece of paper and lay it horizontally on top of a glass. Place a book above the paper close to, but not touching the paper. Rapidly lift the book. What happens? The paper should rise to follow the book. Why? Lifting the book reduced the pressure above the paper, and the paper was lifted up into that lower pressure just like you are lifted up in flight.

Lift is good, drag is bad, but we need them both to fly. By learning how to manipulate the total drag on our airfoils we can greatly improve our in-flight performances. There are 2 basic types of drag that act on a paraglider in flight:

Parasitic, or form drag; is the drag that occurs in moving the basic shape of the wing, lines, and pilot through the air. It is easy to demonstrate form drag. Drive down the road in your car with the window open, and hold your hand out the window vertically. If you are traveling slowly, it will be very easy to hold your hand in place. As you increase speed you will find it increasingly difficult to keep your arm from being blown back as the drag increases. Turning your hand so it lies parallel to your direction of travel should significantly reduce the drag, making it easier to hold your arm in place. ***Note* It should be obvious, but do not try this in a fast moving vehicle***. A good friend and fellow pilot tried this in flight by opening the storm window of a piper arrow whilst I was flying at around 160 MPH. He succeeded in breaking 3 fingers when the air loads smashed his hand against the rear of the opening!

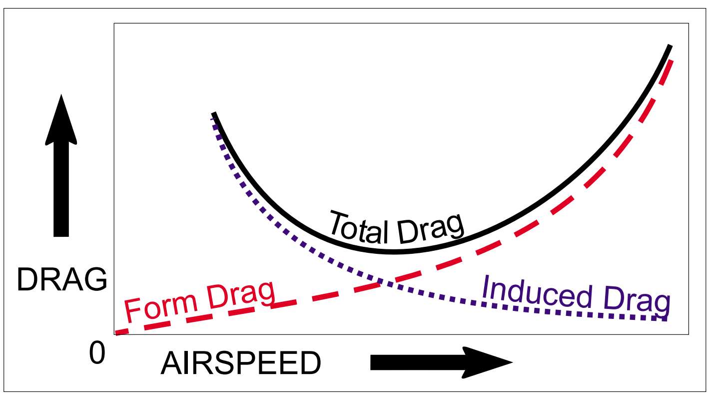

Figure 1 • Drag Curves

Looking at the graph in figure 1, you can see that there is no drag at zero airspeed, and the drag increases exponentially as the airspeed increases. Theoretically, drag increases as the square of the speed. Which means if you go twice as fast, the drag increases 4 times. On conventional aircraft this drag force is dramatically higher than a paraglider due to the higher speeds achieved. That is why they go to great lengths to retract the gear, and generally make the aircraft as smooth as possible. Due to the lower speeds a paraglider flies at, the benefits of streamlining are not as effective, but reducing the drag of moving the profile of the wing and pilot through the air definitely has a positive effect. You see this manifested in competitions by pilots wearing smooth tight fitting flight suits, assuming a reclining posture, using tear drop shaped helmets,and using microlines to attach the pilot to the wing.

Induced drag is a little harder to quantify, but it is essentially created as a byproduct of generating lift. We all know that there is a higher pressure located under the wing, and a lower pressure area on top. We were taught that this differential pressure, along with the downward deflection of the airflow, generates lift that enables us to sustain flight. We have generally not been concerned with how these pressure differences effect the spanwise movement of air, but this movement is extremely important, as any mixing increases the induced drag produced by the airfoil, and even destroys the lift around the wing tips.

If we sum up the pressures surrounding the wing, we find that the pressure is highest in the center of the underside of the wing and lowest at the center of the top of the wing. As the air flows over the wing it is deflected away from the higher pressure underneath the wing, and towards the lower pressure on top of the wing. This causes the airflow over the wing to be deflected in a spanwise direction outwards away from the higher pressure on the bottom of the wing, and inwards towards the lower pressure on top.

As the air leaves the trailing edge of the wing it has a rotation imparted to it because of the spanwise shift in direction of the air. This rotating mass of air grows together to form two distinct trailing vortices that trail behind the wing, moving counterclockwise on the right and clockwise on the left, as viewed from behind the wing. This twirling mass of air is what causes the drag associated with the lift generated. It tries to suck the wing backwards to fill in the voids created, much like someone hanging on to the bumper of your car as you leave a stoplight. This effect is illustrated in figure 2.

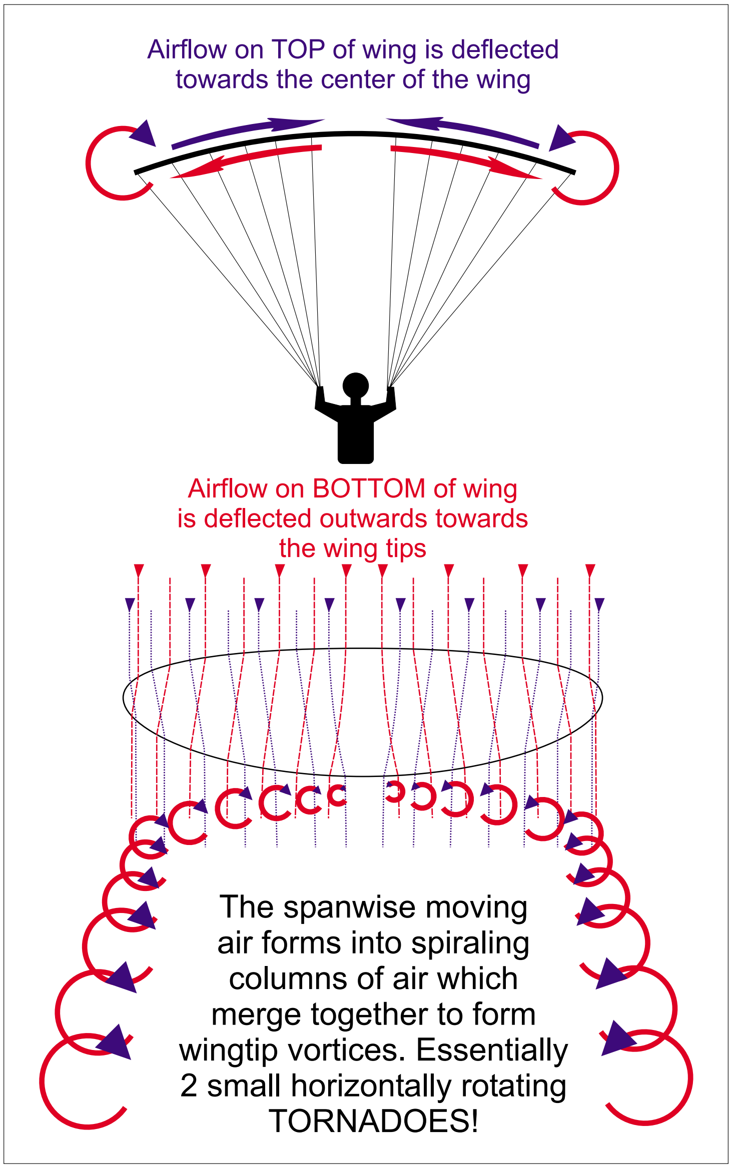

Figure 2 • Spanwise movement of air

These spiraling columns of air are really mini tornadoes moving in a horizontal direction, and should be treated as such. For reasons we will delve into a little later, heavily loaded wings, moving at high angles of attack can generate enormous turbulence. If you want to see a graphic display, go to any large airport when it's raining lightly, or foggy, and you can actually see the vortices trailing off the wingtips of all aircraft. Light aircraft have been thrown inverted, or slammed into the ground behind heavier aircraft when they encounter wake turbulence during takeoff or landing. If you fly into the wake of another glider, particularly a heavily loaded slow moving one; you stand a good chance of encountering anything from a little whack, to a complete collapse of your wing, depending on how you enter or cross the wake.

The induced drag created by moving a wing through the air is directly related to the aspect ratio of the wing. Aspect ratio is the ratio of the average wingspan divided by the average chord. Looking at figure 3 we can see the effects of two different wing planforms of equal surface area. On the left is a short, fat, low aspect ratio wing typical of the entry-level glider. On the right is a high aspect ratio wing typical of the intermediate or competition level gliders. You can see that high aspect ratio wings generate less induced drag, since the air has less distance to travel, hence the deflection of the air, and drag produced is minimized.

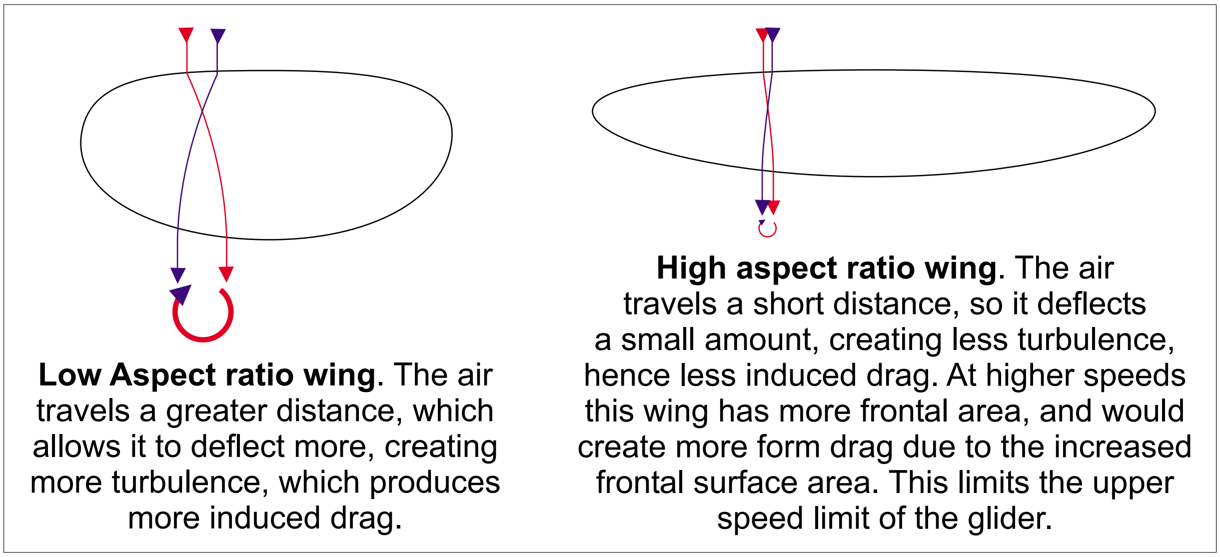

Figure 3 • Effect of Aspect Ratio

Induced drag increases as speed decreases because of the spanwise defection of the airflow. If a wing is moving quickly through the air it doesn't get much chance to bend spanwise. Slow the air down as it moves across the wing, and the air will deflect further. This increases the mixing, and generates larger vortices, and increased amounts of induced drag. The drag will continue to increase until the point at which the wing stalls.
If you have ever looked at a fixed wing glider, you have probably noticed their long slender wings. When you consider they are generally flown at slow speeds you can rationalize the reason for the design. Since they fly slowly, form drag is a much smaller concern that induced drag, and induced drag requires the short chordline to reduce the time the air is moving across the wing. Conversely fast moving aircraft are much more concerned with the increase in form drag, and a long wing imparts a heavy form drag penalty. To reduce this drag, they generally have short, fat wings. Since the air is moving quickly across these fat wings, it gets little chance to be deflected spanwise, hence induced drag is not a significant concern.

Since paragliders generally spend most of their time operating at slow speeds, reducing the induced drag generally produces better performance than reducing the form drag of the wing. This might lead one to the conclusion that a long skinny wing is best for our needs. As evidence has born out, a few designers may have pushed this a wee bit to far, resulting in wings that were prone to catch many pilots by surprise.

Our next installment continues, as we take a look at the polar curve for our wings, and how we can use the information they provide us to maximize our in flight performance…..