THE CANOPY PILOT'S HANDBOOK

By Bryan Burke
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SKYDIVE ARIZONA

4900 N. Taylor Road
Eloy, AZ 85231

edited by Johanna Faust

INTRODUCTION

The following materials are presented to the skydiving public in the hopes of bringing up our level of performance and understanding. Anyone is free to copy this material. However, you are on your honor not to plagiarize or edit my work. If you choose to copy this material for instructional purposes, fine. All I ask is that I am credited as author and Skydive Arizona is also given credit, since these materials were developed partly on their time and with their instructional programs in mind. In addition, please do not change the text. If you feel the need to add to, subtract from, or contradict something, please do it in the form of foot notes. I look forward to hearing from anyone with comments, criticisms, or suggestions - but when it comes to adding or subtracting from the text, I reserve the right to do it myself.

At this time the Canopy Pilot's Handbook consists of five chapters. I plan to add a sixth chapter, on precision landings for modern parachutes, by the fall of 1997. There is an additional section at the end directed to people who may wish to teach canopy flying courses at their own drop zone. It offers a few suggestions. I would like to hear from people who host such courses; perhaps we can come up with some common denominators that will lead to better teaching.

Most of the material presented here came from long observation, experience, and thought. There aren't many sources of information out there, and some of those are incomplete or even inaccurate. But there are some good ones. Works that particularly influenced me are:

The Parachute Manual (v.II) by Dan Poynter. This fascinating volume (and v.I for the really hard -core enthusiast!) has a place in the library of any skydiving professional, especially riggers. For typical skydivers the $49.95 price tag is a bit high, since two thirds of the book is devoted to specifics of rigging that aren't much use to the layman. The last third of the book, however, has interesting discussions on design, deployment, packing, malfunctions, etc. Some of the material is a bit obsolete since the latest revision that I know of was in 1991. Most research libraries have this book in their collection, so try the nearest university library or your local rigger if you want to look at the book before you lay out fifty bucks. It can be ordered through any of the big mail order parachute suppliers or direct from Para Publishing, PO Box 4232, Santa Barbara, CA 93140-4232, USA.

The Aerodynamics and Piloting of High Performance Ram-Air Parachutes by Jerry Sobieski. This is a very interesting treatise on how modern parachutes fly. Although it is written in the style of a college thesis even someone like me, who flunked calculus, can understand it. The first forty pages are a detailed technical analysis of how parachutes fly; the remaining thirty are about how to fly them. The author's e-mail address, last I knew, is jerrys@umiacs.umd.edu. The treatise can be found on the skydiving archive at http://www.afn.org/skydive. Quite a few other interesting things are there too; just browse through the safety and training section for information specific to canopy flying.

The owner's manuals that accompany new canopies usually have at least one or two useful nuggets of information. Performance Designs also has published two sets of lecture notes written by John LeBlanc. John is a very interesting man to talk to and gives seminars on canopy flying at many boogies and other skydiving events. You may want to contact PD and get these two notes. They are also available on the skydiving archive mentioned in the previous paragraph.

Talk to canopy manufacturers if you get the chance. Most of them have thought deeply about parachute performance. Unfortunately they tend to be a bit cagey when you get down to specifics of design, since they consider some of this information proprietary, and possibly potential liability. Still, most have some very interesting views on the subject. Most of them are also very busy people, so be sensitive to the possibility that they might not have a lot of time for idle chatter.

Most of all, keep your eyes open. In your skydiving career you will see far more landings than you will ever make. All of them are learning opportunities.

Blue skies, soft landings

Bryan Burke
Safety and Training Advisor at Skydive Arizona

USPA National Director, 1997-98

Chapter One: *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 maneuvers.

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 maneuver 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 maneuvers 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.

Center of Mass, Center of Lift

The center of lift is a point on the wing where the lift can be thought of as concentrated. The center of mass is where the weight of the system is focused. On a sport parachute the weight is clearly centered well below the wing, in the form of the pilot. By changing the relative position of the center of mass to the center 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 maneuver 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.

Chapter Two: *DESIGN PARAMETERS*

Individual canopies can be described in terms of wing shape, trim and loading. The designer determines the first two, the jumper the latter. Choices on these items determine the way a particular parachute flies, so without even jumping a canopy you can deduce to a great extent how it will fly if you understand these features. Wing shape is defined by aspect ratio and airfoil section. Aspect ratio is the ratio between span (side to side width) and chord (front to back.) Airfoil section can be thought of as the ratio of the wing's height to it's chord. Trim is adjusting the particular wing shape to the apparent wind to gain the best compromise in performance characteristics. And wing loading is the choice of how much power the pilot decides to give to the system.

Aspect Ratio

In theory, high aspect ratio canopies fly faster because the higher the aspect ratio, the lower the form drag for the amount of lift produced. In other words, a 200 square foot nine cell produces more lift than a 200 square foot seven cell for the same amount of form drag. Why not build a 200 square foot eleven cell at a very high aspect ratio?

The practical limits of aspect ratio are reached at about 3 to 1. At this point, a designer runs into several problems. Unlike an airplane wing, a parachute has no solid structure but maintains its shape through air pressure. To fly well the canopy must maintain good internal pressure in every cell. The higher the aspect ratio, the more difficult it is to pressurize the end cells. The wing needs to maintain a clean shape, too, which means more lines and ribs. But these mean more drag.

High aspect ratio canopies have a shorter control (toggle) stroke and therefore react more sharply. They tend to stall more sharply and inflate more unevenly than low aspect ratio canopies. Although it takes longer to initiate a turn on a high aspect ratio canopy, once the turn is under way it will be at a higher rate than a low aspect ratio canopy of the same surface area. Finally, more parts (cells, ribs, and lines) found in a high aspect ratio canopy means more pack volume for the wing area.

Between pressurization, diminishing returns on drag, and managing deployment of the canopy, the highest aspect ratio canopies on the market have never passed about three to one. Most nine cell canopies approach three to one; most seven cell canopies fall in the 2.2 to 1 range. Which is better? Everything has its price. A nine cell should fly faster than a seven cell because of less form drag - but it has 20% more lines, ribs, and cell openings than a seven cell - all contributing parasite drag. Throughout the 1990s prevailing wisdom has been that nine cell canopies also have better glide than seven cells. But the definite speed and glide advantages shown by nine cell canopies in the past decade may be largely a function of different foil sections and trim angles combined with more efficient construction. Time will tell; as designs improve seven cells seem to be catching up to nine cells in many aspects of performance but we can still expect high aspect ratio canopies to have more efficient gliding characteristics.

Because they tend to have more predictable inflation and stall characteristics, virtually all reserves are seven cells. So are canopies specialized for accuracy landings, canopy relative work, or fixed object jumping - applications where opening and slow speed flight characteristics are more important than speed and glide.

Foil Section
The foil section of a canopy is defined by the shape of the ribs - a "side view" of the canopy. Generally speaking a slow flying wing must have a thick foil in order to produce lift. (The reason for this is in chapter one but you will have to think about it!) The penalty is that a thick foil has more drag than a thin one. An accuracy or CRW canopy might have a foil section of 15 to 18% of the chord, while a high performance RW canopy might only have a 10% section. Although the thinner section fli es faster, it has less lifting ability at slow speeds and will have more abrupt stalls and turns. The actual curve of the foil is also important. If the center of lift of the foil is far forward, the canopy will have a high descent rate and very solid pres surization. Putting the center of lift further towards the center of the chord creates harder to pressurize the canopy. Combining this type of foil with a high aspect ratio will cause the leading edge corners to collapse in turns. Elliptical canopies are designed to address this problem: sweeping the leading edge back and reducing the size of the outer cells seems to increase the pressure in the end cells. As an added benefit, ellipticals feel the effects of a steering input more (proportionally more of the outside section of the wing affected by toggle input) giving very snappy response.

Summary
Here are some general guidelines about airfoil design, given a seven cell and a nine cell canopy of the same surface area.

- The seven cell is more likely to open on heading, will pack slightly smaller for the same wing area, and is less vulnerable to malfunctions of a line-over type. In a partial malfunction situation, the seven cell will be less radical (have a slower descent rate and less violent behavior.)
- A nine cell will have a flatter glide, giving it slightly more range. It will have a longer flare, which may make the flare easier to time but requires a longer runway.
- The seven cell will be more stable at slow speeds, give more warning before stalling, and recover from a stall more predictably than a nine cell.
- The nine cell may have more forward speed, an advantage in winds.

Wing Loading
This term refers to the amount of weight a parachute is carrying and this is probably the single most important factor in how a modern parachute flies. In the U.S. wing loading is expressed as a ratio of pounds per square foot. For pounds, use your exit weight: combine the weight of your body and all of your equipment. For square footage, use the manufacturer's figure. Then divide the weight by the square footage for the wing loading. For example, I weigh 190 pounds and my equipment weighs another 25, including main, reserve, container, jumpsuit, and paraphernalia. That makes my exit weight 215 pounds. If I am jumping a 205 square foot canopy, my wing loading is 1.05. A student my size under a Manta (288 sq. ft.) would have a wing loading of .75. Someone my size under a Sabre 150 would have a wing loading of 1.43. Most manufacturers will have a suggested maximum wing loading for various designs; many also suggest a minimum.

As a rule, the higher the wing loading, the higher the performance. At very low wing loadings, canopies are sluggish and unresponsive. Increasing wing loading increases forward speed and descent speed. This increased speed gives you a higher turn rate, and the controls will feel more sensitive. Keeping in mind that lift increases with speed, a high wing loading can mean that you get a longer flare than you would with a low wing loading. But since everything happens faster, your room for error is reduced. Partial malfunctions will be more severe with an increase in wing loading.

There is a point of diminishing returns with wing loading. Using an airspeed indicator and variometer (a device to measure descent rate) to test a variety of modern canopies, I found that at wing loadings above 1.5 the only performance increase is in turn rate and responsiveness. As more weight is added, the canopy loses glide (comes down faster) with no gain in forward speed. For general canopy flying, loadings above about 1.4 seem to confer zero benefit to speed and glide while increasing descent rate. Stall speed (the point at which flow separation occurs) also goes up as the wing loading increases.

Here are some general guidelines about wing loading given canopies currently on the market in 1997:

- For slow, soft landings, or for jumping at higher elevations, choose a low wing loading: .7 to .9.
- For a good compromise of performance and safety, jump a 1 to 1 wing loading; one square foot of canopy for each pound of exit weight.
- For a fast canopy, jump at a wing loading of 1.1 to 1.3. Any wing loading over 1.3 puts you in the experimental category, where the canopy is at the edge of its performance envelope. Experts routinely jump at wing loadings of 1.4 to 1.6 - but they are jumping in the same conditions, every day. Changing landing areas, altitude, or other factors make these wing loadings questionable.
- As a rule, zero porosity canopies and 9 cells can be safely flown at higher wing loadings than F-111 seven cells. A skydiver who might jump an older seven cell at a .8 wing loading could, with a little training, safely jump a modern zero porosity 9 cell at 1.1.

Trim

How a parachute is trimmed and tuned has a great effect on its performance. Trim refers to the angle at which the parachute is set to descend - the angle of incidence. Nose down trim results in a higher descent rate and increases stability. Nose up provides more glide but makes the canopy less resistant to turbulence or deformation and such a canopy will also take longer to re-inflate once collapsed. Typically, Accuracy and CRW canopies are trimmed nose down (steep angle of incidence) while RW canopies have a flatter trim. Trim affects the flare in the same way it affects glide. A canopy with a steep angle of incidence will not flare very long, but the canopy will be more stable in brakes and recover from stalls faster.

Steering line trim also affects canopy performance. Having the steering lines too long diminishes the effectiveness of control input and might mean the jumper is not getting the full potential out of the parachute at flare time. If the lines are too short, the canopy will always be in partial brakes and will be easy to flare past the stall point. Just moving the point where the toggle is tied to the steering line an inch up or down can make a big difference in your parachute's flare characteristics. If you have trouble slowing the parachute down on a calm day, chances are your toggles are too low. If your canopy rocks behind you on landing and is easy to stall, you may need to lengthen your steering lines.

Trim isn’t always controlled by the manufacturer. Over time, lines stretch and wear. On higher performance canopies, an inch or two either way makes a big difference. Canopies need to have the lines replaced periodically as they come out of trim. Yet the same skydivers who would meticulously change oil or replace tires on their car may never think about how their canopy holds up over time.

Parachute Materials
The standard parachute nylon throughout the ‘80s and early ‘90s was F-111, after the designation given to it by the mill that produces it. Lately coated fabrics, commonly referred to as "zero-p" fabrics, are taking over the market. F-111 is less expensive and easier to work than zero porosity fabrics, which means parachutes of this material are cheaper. They are also easier to pack because air escapes from this fabric more easily than from zero-p. However, they wear out sooner. An F-111 canopy is at its prime for about 300 jumps, will work well for another 300, and will have lost a lot (20% or more) of its original performance by the time it reaches the last 300. Few F-111 canopies are any good after 1,000 jumps.

Zero porosity fabric is more expensive and harder to work with than F-111, so canopies made from it are more expensive. However, the expense is offset by several advantages. Zero-p canopies hold their shape better and less air passes through the fabric, giving them better flight characteristics than a similar canopy built of F-111. They also last much longer, and zero-p canopies may still fly well after 1,000 jumps. They have the disadvantage of being more difficult to pack - until you get used to them, which only takes a couple dozen pack jobs.

Some canopies combine the two fabric types for the best of both. These seem to work well.

Canopy Material	Advantages	Disadvantages
F-111:	Cheap Easy to Pack	Less Aerodynamically Efficient Good for only 600 - 700 jumps
Zero-P:	More Aerodynamically Efficient More Durable	More Expensive Harder to Pack

Parachute Lines
There are two basic types of parachute line, regular dacron line (the thick type) and microline or spectra (the thin type.) Microline is more expensive than dacron, adding to the cost of the parachute. However, since it is significantly smaller, it reduces drag, giving perhaps a 5% performance increase over a canopy equipped with regular line. Microline is very strong and does not stretch much when weight is applied, as dacron lines do. This means that it tends to cause harder opening shocks. It may also shrink unevenly over time, causing a canopy to get out of trim. Some people find it slightly harder to handle and stow, and it is inappropriate for canopy relative work.

Line Material	Advantages	Disadvantages
Dacron:	Easy to pack Soft Openings	Bulky More drag
Microline::	Low drag Small pack volume	More expensive Harder openings

Other Modifications

Most skydiving equipment comes in a fairly stock configuration, but there are a number of small modifications you can make to the risers and canopy to improve flight characteristics. Not all of them are useful for everyone, but by customizing your gear you can get as much as a fifteen percent performance increase. Enhancements come in two forms; those that reduce drag and those that improve handling.

Reducing parasite drag has obvious benefits because by increasing speed you increase the lift your canopy produces without adding any weight to the system. The most common ways to do this are removable sliders, collapsible pilot chutes, and riser modifications. All of these are fairly simple modifications you can usually order from a dealer or have made for you by a capable rigger. But since they do require a little knowledge to use safely, be sure to get advice and instruction from someone familiar with the modification.

Slider Modifications

A slider is essential to deployment but serves no purpose once the canopy is open. From there on, it is just a burden to the canopy. If you think the drag is negligible, drive down the road at 25 mph holding your slider open. Getting rid of the slider provides another benefit by letting the canopy spread out more towards its original ideal design shape, reducing some of the anhedral of the parachute and giving a slightly flatter flight. Removing the slider not only increases a canopy's performance, it confers aesthetic benefits too by eliminating a lot of noise and greatly improving the view.

There are a number of ways people have dealt with the slider. Each has pros and cons. On every system, the biggest con is that you have to deal with your slider after opening. Remember that stowing your slider is not nearly as important as managing your flight - other traffic and the spot - so never mess around with your slider until you have a safe path back to the dz picked out!

The most common way to eliminate the slider is to pull it down and stow it under your chin or under a velcro strap on the neck of your jumpsuit. The good part of this method is that it is a very simple system in that it does not add significant time to packing and can't be screwed up at packing time. However, it doesn't work if you have thick risers instead of mini risers. If you pull it under your chin, it can blow loose and block your vision. If you wrap somebody or induce a malfunction after stowing it behind your neck, when you cut away your canopy might stay with you! Both the latter cons have occurred with disastrous results. Finally, do not put bigger grommets on your slider to ease the pull down unless you put correspondingly big stops on your canopy's stabilizers or you will get an exciting malfunction!

Fairly common is to leave the slider in place but collapse it with a drawstring. Actually, all this does is silence it a little and reduce some drag, so although this is the simplest possible solution to the slider, it is also the least effective.

Splitting the slider is common with accuracy canopies because it allows the canopy to spread out, it works with big risers and is fairly simple to use. This method is fine for slow canopies because the slight drag from the split slider isn't as much of a factor on an accuracy canopy - they have drag all over them anyway. Aesthetically, split sliders are rather ugly.

Removing the slider altogether is the final option. Removable sliders use a loop and pin system, kind of like a tiny toggle stow, that holds the grommets onto the fabric. To remove the slider you grab a loop in the middle of the slider where lanyards from the four corners come together. A quick tug and the fabric is loose in your hand. You then have to stow the slider in your jumpsuit or some other place where you won't loose it. The grommets of the slider remain at the top of the risers. Before packing you re-attach the slider, which adds a minute or two to the packing process. Because you definitely do not want to hook it up wrong, it is important to pay attention to the re-attachment.

Collapsible Pilot Chutes

Collapsible pilot chutes are another easy after market feature to add to your parachute. There are two types. Bungee collapsed pilot chutes are simple in that they do not need to be "cocked" to work, as kill line collapsibles do. Their disadvantage is that if the bungee is worn out or when deploying at slow air speeds, they can fail to inflate and cause a pilot chute in tow. Kill line types are the opposite - they work well in most deployment conditions, but if they aren't cocked before packing, you get a pilot chute in tow. As long as you understand and properly maintain the type you have, there should be no problems.

Both types have a somewhat bulkier, stiffer bridle than non-collapsible types. This may increase the probability of tying a knot in the pilot chute as it is inserted in the pocket. I have seen this problem several times and there seems to be a high correlation with collapsible pilot chutes, so be very careful about the packing technique you use.

Riser Modifications

Being able to steer with your front risers adds considerably to your piloting options, yet a stock riser can be hard to grip. Furthermore, as you turn the tension on the riser increases with the weight increase induced by centrifugal force. Therefore, most advanced canopy pilots have some kind of hand hold added to their risers. These usually come in the form of loops or blocks.

Front riser loops are loops of webbing sewn to the riser. Blocks are a stiffener of some kind, usually folded webbing or a metal ring, that is placed just below where your hand grabs the riser. The block keeps the riser from sliding through your hand when you pull on the riser. The advantage to loops is that they have little bulk and won't catch on anything during deployment. However, you have to actually get your hand in and out of them. Blocks are simpler: you just grab the riser and close your hand around it. Open your hand, and you are free of the riser. For this reason canopy relative workers have a preference for blocks, as do many advanced canopy pilots.

Some pilots of small, high aspect ratio canopies have three risers instead of two. The third riser is for the steering line. This modification, like a removable slider, allows the canopy to flatten out, improving the shape and therefore the performance. The fact that third risers are uncommon may indicate that the increased performance may not be worth the increased complexity.

A final modification seen on a few canopies is trim tabs. These allow the pilot to mechanically lock in a certain amount of front riser trim. Trim tabs were fairly common on CRW canopies in the early and mid 80's but are now rarely seen. They add some bulk to the riser but are only occasionally of any use.

Chapter Three: *ENVIRONMENT*

Weather

The environment in which you fly your parachute includes a large number of variables, any one of which can contribute to an accident. Let's look at some of the many things that affect your canopy.

Turbulence

Turbulence can be described as a disturbance in the air. Several things can cause turbulence that can affect a canopy in flight. Among them are wind, heat and wake turbulence.

Wind over an uneven surface or a temperature gradient creates turbulence. The amount of turbulence increases geometrically with the wind speed. In other words, a building that creates negligible turbulence in a 10 mile an hour wind can create extremely dangerous turbulence in a 20 mile an hour wind. Turbulence extends far downwind of an obstacle. Visualize the wind as flowing water. A line of trees or a long building will have a definite downward wave behind it. A single obstacle such as a building will have both sideways and downward turbulence. For a graphic demonstration, stand behind a large building on a windy day and note which way the wind currents are where you stand. Odds are they will be quite different from the general wind direction.

Dust devils are caused when a small area of air is heated above the temperature of the surrounding air. These miniature tornadoes create severe turbulence in an area up to a hundred or more yards wide. They can easily collapse all or part of a canopy. They can also cause downwind landings, either by causing a false reading on wind indicators or by changing the wind direction in their immediate area.

Wake turbulence is a common cause of hard landings in a crowded landing zone. A canopy's passage through the air leaves a wake similar to the one behind a boat. The wake has two characteristics. One is general turbulence directly behind a canopy that can drastically increase the descent rate of a parachute flying through it. This occurs because the "bumpy" air reduces the lifting force of the canopy by disturbing the airflow over the wing. The other wake turbulence is from "tip vortices," which spiral out from the edges of the canopy. These occur because air tries to move from the high pressure bottom skin to the low pressure top skin. It takes the path of least resistance, which is towards the sides of the canopy. As it spills off the end cells it creates a circular wake trailing behind each wing tip - just imagine the V shaped wave behind a power boat. These are essentially miniature dust devils and can easily collapse an end cell or two. Both types of wake turbulence extend well behind the canopy - as much as fifty feet or more - before becoming insignificant. An interesting exercise is to open high with a friend and intentionally fly through their canopy wake to get an idea of how your parachute handles turbulence.

Last but not least, don't land behind the airplanes when the engines are running!

Density altitude

Thin air reduces a wing's performance. Two things cause air pressure to drop: heat and altitude. Therefore, you can expect that a canopy that performs well at sea level on a cool day will fly significantly worse at high altitude on a hot day. As a rule of thumb, count on a 3 to 4 percent performance loss for each 1,000 foot elevation gain or each 10 degrees temperature increase. Using this rule of thumb, a parachute taken from sea level to a 3,000 foot high dz would lose about 10% of its efficiency if the temperature remained constant. Or, jumped at the same sea level dz on a 70 degree day and a 100 degree day it would show a comparable change in performance. Humidity also decreases performance

Traffic

At a large drop zone it is not uncommon for twenty or more skydivers to share the landing area. As more and more of these jumpers use fast canopies, traffic becomes a real hazard. We all know that auto traffic follows certain universal guidelines to minimize collisions. The same is true of aircraft and boats, and even in the freefall portion of skydiving. Yet for some reason, skydivers have been reluctant to adopt standard traffic patterns under canopy even though this simple idea could prevent several injuries and fatalities annually. By following some simple guidelines, you can be a good citizen in the skydiving community, minimizing risk to yourself and others while still having fun.

Break-off and Deployment

Traffic management actually begins at the dirt dive. Be sure you plan a break off altitude that will allow plenty of time to get away from others and still be open by at least 2,000 feet. USPA’s Basic Safety Requirements specify container opening by 2,500 feet for intermediate level jumpers (A and B license) and 2,000 feet for advanced jumpers (C and D license.) The custom for many years has been to break off at 3,500 for small RW groups and USPA recommends 4,000 feet for groups of six or more. But in the modern canopy environment, we should reconsider these numbers. The advent of "fast" canopies has had two effects on the break off and deployment section of the skydive. One is the issue of how much separation from other canopies is enough. The other is how much time a jumper might want to deal with a malfunction on a modern canopy.

At Skydive Arizona, canopy collisions at the deployment phase cause one third of fatalities - more than any other type of accident. To minimize risk skydivers need to minimize the causes of these collisions: off heading openings and inadequate separation. In an ideal world where canopies would always open on heading it would suffice for everyone to turn away from the center and deploy. We’ll discuss controlling the openings later, but right now, let’s talk about the real world of canopies that occasionally open off heading. That’s when adequate separation becomes essential.

How much separation is enough? Typical modern canopies fly forward at about 35 feet per second while the brakes are still set in deployment configuration. When facing another canopy as a result of off heading openings the closing speed can be up to 70 feet per second. With brakes off, it is more like 90 feet per second. Given that it will take about three seconds to recognize the emergency and begin appropriate action, deploying within 200 feet of another skydiver is very hazardous. A good skydiver can attain speeds of 80 to

90 feet per second in a track - but it takes time to turn, build up speed and then wave off and slow down the track. To turn 180 from the formation, begin a track, sustain a good track for at least three seconds, and then wave off is the work of at least eight seconds - 1,500 feet of altitude at the minimum. That means that if you want to initiate deployment at or above 2,500 feet, you need to break off at or above 4,000 feet. More tracking time means a higher break off.

Although details on tracking skills fall outside the scope of a treatise on canopy control the collisions that might result from poor break offs are part of the subject. Learn how to "flat track" from an experienced RW jumper - just watch the break offs from the ground and you will be able to figure out who has mastered the technique. But there is much more to separation than how effectively you can track. An important thing to keep in mind is that the fundamental goal of break off is to deploy your parachute in clear airspace - not necessarily the same as being able to track fast and far.

For example, if two skydivers find themselves tracking in roughly the same direction at 4,000 feet, they have a traffic problem. If both continue to track, at 2,000 feet they will have the same traffic problem and no altitude in which to fix it. In this situation, the higher (or further behind) skydiver should wave off and deploy as soon as he knows there is no one above, behind, or deploying to the side. Similarly, it makes sense to have one person pull in place (customarily the video man, if there is one) while the others track away from the center person.

Separation is one way to minimize the risk of collisions. Controlling the deployment is another. Most off heading openings, line twists or snivels are caused by either packing or body position. Be sure to pack as symmetrically as possible. Since this discussion is on canopy flight, not packing, you will need to get this information elsewhere. BASE jumpers and canopy formation enthusiasts are good sources for packing tips that will contribute to on heading openings.

Body position is as crucial as packing technique. To understand this, next time you are under canopy raise your right knee as high as you can and twist your shoulders to the left. You should notice a left turn (assuming your canopy flies straight in normal flight!) The turn will be more pronounced on higher performance canopies. Now imagine how much more air is affecting your canopy during the deployment phase, when you have considerably more speed. Having a shoulder down (looking behind is a common cause) can result in off heading openings or line twists. To prevent this, as you track away clear the air to the front, sides and below. Looking behind is largely a waste of time and awareness. Your job is to ensure no one is deploying below you.

When the time comes to deploy, wave off and throw your pilot chute. As you do so, pick a point on the horizon straight ahead. When the canopy deploys, it may have an inclination to turn right or left. Concentrate on holding your shoulders square and towards your heading point. If the canopy turns right, twist your shoulders back towards the heading. As the canopy fully inflates, grab risers or toggles and steer towards your heading. Turning back onto the heading will keep you flying away from others until you have a chance to ensure the space around you is clear.

Traffic management under canopy

Once under canopy, immediately clear your airspace. This means checking for potential collisions before you do anything else. Releasing brakes, stowing sliders and heading for home are all secondary to collision avoidance. If you are faced with a collision, the general rule is to turn right. Practice using front and rear risers for this. Front risers will cause sink, rear risers cause float. Altering descent as well as direction should be practiced until it becomes second nature.

As you head for the dz, there are a couple things you need to check as soon as you have cleared your air and have your canopy in hand. Is anyone under their reserve? If so, go to their aid by following them or their equipment - the main and free bag. Ideally someone will follow each item to ensure recovery. This is your duty to all fellow parachutists, whether you know them or not. Sooner or later you will be under your reserve, watching your main canopy drift away from the dz at sunset. When it happens, you will be glad to have some company.

Assuming all is well your next task is to obtain as much vertical separation from the other skydivers as you can, assess the spot and choose your landing areas. We'll hold off discussion of bad spots until later, while we continue to look at traffic. Assuming you can make it back to the intended landing area, while you are flying along take stock of the other canopies. With practice you will be able to recognize the types, speeds and altitudes of other canopies. Compare them to your own and begin the process of vertical sorting. Low canopies with high descent rates should maintain a fast descent rate to increase separation from higher canopies, while higher canopies should slow their descent.

Regardless of design specifics a typical modern canopy will have a broad range of descent speeds. In full glide most canopies will descend at 1,000 to 1,500 feet per minute. The same canopy in one half to two thirds brakes will descend at 600 to 900 feet per minute. In a turn, it can easily reach descent rates of 2,000 feet per minute. Therefore, most canopies have a range of descent rates of at least 1,500 feet per minute. By taking advantage of this a wise canopy pilot can ensure that of the twenty people he was on the plane with only two or three will be landing at the same time he is. A helpful hint: most people are better at sinking than floating. Learn how to slow your descent rate and you can have the landing area to yourself. The added advantage is that you get to watch everyone else land, giving you extra information about ground winds.

Final Approach

Eventually it will be time to enter the landing pattern. Like the break-off, this is a very dangerous part of the skydive. A good approach is more than aesthetically pleasing - it can be the difference between life and death. What makes for a good traffic pattern? Whether your style is aggressive or conservative, an elegant landing is characterized by these features.

- **The initial approach is easily understood by other canopy pilots in the air.**
- **The turn on to final approach does not intersect the flight path of other canopies.**
- **The entire approach and landing is done in such a way that it does not cross a straight ahead, conservative approach to the center of the landing area.**
- **The approach is not directly over or next to any bystanders.**

Most landing areas will have some buildings, roads, fences or other obstacles that affect the pattern. With airplanes, the convention is to use a left hand pattern - one that uses only left turns onto the different legs of the approach. That makes sense because the pilot sits on the left of the plane and has better visibility that way. With parachutes the situation is different. Some drop zones like a left hand pattern so everyone does the same thing. Some allow either left or right patterns to allow skydivers of different experience levels to split up the landing area and control what obstacles they will have to fly over.

Canopy and pilot types also affect the pattern. Generally I find they can be broken down into two classes: conservative approaches used by novices or other people inclined towards caution, and aggressive approaches used by sky divers with high performance canopies. Since these types may be about equal in numbers, the vertical separation mentioned earlier is critical. Even so, we can expect a few of each category to be landing simultaneously. How do we keep the two incompatible styles safe?

Let’s use Skydive Arizona as an example. We allow skydivers to choose either a left or right pattern. Our primary landing area is about 80 meters wide from north to south. On a day when landings are to the west, people using left hand patterns should approach over the buildings and land within 20 meters of the fence. By local custom this pattern is reserved for fast canopies and experienced pilots. They have the skill to land near obstacles, and it keeps them out of the rest of the landing area. People using right hand patterns should land well to the north of the gravel target in the center, leaving that area free for people using a straight in approach.

The less experienced jumpers stay out over open desert and land further away from the fence. Their main concern is to avoid overshooting the landing area and ending up on the asphalt taxi way. But imagine the wind shifting to either the north or the south. Now a new set of problems arises - the danger of undershooting or overshooting the landing area.

In general, overshooting is a problem on calm days; undershooting, windy days. Instead of thinking of landing on a circular target, imagine a runway. Depending on your skill level and canopy type, always give yourself a long enough runway so that whether you land long or short you will not be faced with hitting obstacles or people. Sometimes that will mean picking an alternate landing area with a little more room, since on a calm day most modern canopies need at least a one hundred yard runway to be safe. The dart board style idea of a landing area has become obsolete - always think of a runway!

Finally, we need to consider the combination of traffic and obstacles. Look at our sample landing area again. Let’s say the wind is out of the west and you are approaching along the fence. If a canopy on a more southwesterly heading lands in front of you, you have no place to go. Choices are collide with the canopy, collide with the fence, or do a sharp right turn out into any other traffic, with the hazards of wake turbulence and low turns thrown in. Many canopy pilots develop the habit of thinking of a certain area is "theirs." If you find someone in "your" airspace, what will you do? Learn to maintain a flexible approach!

Low speed approaches have their own set of problems. Using deep brakes or "S" turns in a crowded landing area is as dangerous as "hook" turns. Do not employ student flying techniques in an area for advanced jumpers.

Regardless of your personal style, the etiquette is:

- Low man (including people on the ground) has the right of way, as do students and tandems.
- Never use an approach that will force traffic behind you to use evasive action or fly through your wake.
- Don’t intentionally land crosswind or downwind: this not only presents a huge traffic hazard, but leads everyone still in the air into a state of confusion.

Any discussion of landing areas needs to address so called "hook" turns. I dislike this term; to me a hook turn is a low toggle turn, not necessarily intentional, that shows a lack of planning or respect for the surroundings. High performance landings are another thing altogether. It is acceptable to blend the turns onto crosswind and final into a single, smooth, carving 180 if it is "round" enough to allow you to alter it in the event of traffic conflict and is intelligible to others as a transition through the customary downwind, crosswind and final approach. A detailed discussion of good high performance technique will follow in the chapter on flying skills.

Just as there are some things that define exemplary landings, there are some that define unacceptable technique. Some common approach errors that are rude or dangerous are:

1) Downwind approaches over the center of the landing area.
In this situation, no one in the air knows which way you intend to turn. For all practical purposes you are obstructing the entire landing area. In addition, you are putting yourself in a situation with no escape routes - if traffic eliminates your intended turn you will be forced to land downwind or execute your turn too low. Therefore, all downwind legs of the approach must avoid flying over the center of the landing area.

2) Sudden, "snap" turns, especially more than 90 degrees.
These turns have several problems. From the standpoint of other traffic, they do not allow you a good view of where you will be going and greatly increase the possibility of a collision. They are also confusing to other canopy pilots.

3) Approaches that may cause you to land crosswind/cross traffic
Due to traffic, obstacles, turning too low, or other factors.

4) Approaches that cross through some or all of the normal straight in approach pattern.
Imagine a line along the wind through the center of the target. No approach should cross this line. If you use a left hand approach, finish on the left side of the line. If you use a right hand approach, stay on the right side of the line.

5) Final approaches that put the pilot over or next to bystanders.
Always remember that many skydivers have poor hearing and may not know where you are if they don't see you. Whuffos have no idea where parachutes will go. Never assume they will stay in place - or move - if you need them to. While striking people on the ground is rare, it should be considered as reprehensible as a motorist striking a pedestrian.

The final aspect of controlling the landing area takes place after you land. Collapse your canopy quickly so no one will hit it. Leave the area promptly; you can discuss the dive somewhere other than an active landing area. In particular avoid the area downwind of obvious landing spots such as the pea gravel. This is where incoming canopies will tend to concentrate. If you are in the pea gravel assume someone is right behind you and clear the area at once. As you depart the landing area, scan constantly for incoming canopies: never assume they see you or that they are in control.

Chapter Four: *GETTING THE MOST OUT OF YOUR CANOPY*

If you watch a busy landing area for a while, it becomes obvious that some skydivers are masters of their canopy. They land gracefully and safely where they want to, every time. It looks effortless. Others do well sometimes, but often seem to be on the verge of losing control. Still others are clearly either novices or intimidated by their canopy - their landings lack precision and grace. And the parachutes aren't the deciding factor. Look closely; some of the best landings will be on older, well worn canopies, while the finest new equipment can be dangerous in the wrong hands.

The difference is in the p ilots. The good ones have an intuitive understanding of aerodynamics and the experience to completely control their environment. And over the years, experimentation has taught them some practical techniques to get the most from their parachutes.

The Spot and the Winds

In the previous chapter we looked at the problem of airspace management without taking the spot into consideration. If you are jumping from a large airplane, or from a small one with a bad spotter, your opening point may be less than ideal. But there is a lot you can do about this under canopy. By learning a few tricks about canopy flight, you can optimize early in the ride where, when, and how you will land.

First of all, keep in mind that altitude is your friend. The more altitude you have, the more options you have. This is another good reason not to pull low. Under an open canopy at 2,500 feet you have forty percent more options than someone in the same spot open at 1,500. This means more time to acquire vertical canopy separation, more time to assess the wind conditions, and if necessary, more alternate landing areas to pick from.

Your first priority after a successful deployment is to avoid collisions. Once that is done, determine where you are and head for the dz. You will already have t his information if you checked the spot during exit or freefall; now you need to decide what to do with the knowledge. Incidentally, I often see people land out because once they were open they stowed their slider, removed booties, or did some other trivial task while flying away from the dz! These things can be done just as easily flying towards the landing area instead of away from it.

Depending on the circumstances you will be in a perfect spot (which we won't consider here) or one of three variations of a not so perfect one: long, short, or off the wind line. In each of these cases there are certain strategies that will help you out. And in all of them your best plan will be influenced by the amount of ambient wind. On a no wind day the plan is the same regardless of position: for the greatest range, trim your canopy for distance. Most parachutes fly flatter, and just as fast, if you hold in a couple inches of rear risers or about one third brakes.

Optimizing Glide

Finding your best glide position takes a little work. A variometer and airspeed indicator designed for hang gliding is ideal, but observation works too. Try flying next to a similar canopy and applying brakes or rear riser trim to flatten your glide. You will notice that you can flatten the glide quite a bit before you loose much forward speed. Another trick that you can use by yourself and which will come in handy often is to learn to visualize your glide. To do this, watch the ground ahead of you. Looking at a point far ahead, you will notice that point will appear to rise relative to you. That means you will land short of the point. Look just a little ahead - the point will sink relative to you, since you will pass it in flight. Somewhere between will be a point that doesn't move - where you will land if nothing changes. (Illustration maybe including into wind and downwind variations.)

With practice, you will be able identify this point quickly. Once you can do so, whether you are facing into the wind or running with it, you can check and see what your best glide is. Generally, when facing into a strong wind you want a steep angle of descent for the greatest forward speed and the least amount of time at the wind's mercy. Full drive (toggles all the way up) will produce the best results when you are trying to penetrate into a strong wind. Front riser input is even better, but few people have the strength to hold down their risers for long.

If you are upwind and have a little breeze to work with, the reverse will be true. In this situation, apply brakes to get your slowest descent rate. Most modern canopies reach their slowest descent in about 50% brakes. You might loose some air speed, but you will gain distance. Why? Let's say your canopy descends at 1,200 feet a minute in full drive but only 800 feet a minute in half brakes. If you are open at 2,400 feet, that means a two minute ride in full drive but three minutes in half brakes. Now, say the canopy will fly 30 miles per hour in full drive, 20 in half brakes. Add a ten mile an hour wind and your ground speed will be 40 and 30 miles per hour, respectively. In two minutes at 40 mph you will cover about 7,200 horizontal feet. In three minutes at 30 miles per hour, you will cover about 8,100 horizontal feet - quite a gain! Therefore, whenever you are spotted long upwind, you are better off using some amount of brakes. How much will depend on the particular canopy, winds and spot.

Spots that are off the wind line are also common. In this situation, don't fly directly towards the dz. If you do so, your canopy flight will take the shape of an arc across the ground as the wind pushes you sideways while you fly forward, constantly changing heading to stay pointed at the target. Instead, take an angle that points upwind of the landing area and again watch your path over the ground. If your ground path is a straight line to the landing area, you are doing fine. If it is curving ahead of you, you are crabbing too much. If the curve sags behind you, you aren't crabbing enough.

Landing Out

Sometimes the spot is so bad all the piloting technique in the world can't salvage it. Landing out is a fact of life. It is also a common factor in landing injuries: an out landing may involve a tight landing zone, no wind indicators, unforeseen hazards, or all of the above. If there is any possibility of landing out, start making your plans up high! In fact, the time to plan for an out landing is before you get in the plane. It is always a good idea to note the prevailing wind direction and speed. Most drop zones will be able to provide an aerial photo showing hazards, good alternate landing areas, hostile neighbors, etc.

If you are landing out and forgot to check the winds earlier, start looking for indicators. Distant fires or dust can help. In areas with lots of foliage, you can sometimes tell by observing grass or trees. If some people are making it back to the dz, watch them: they will be close enough to see the wind sock. You can also look for cloud shadows on the ground. For that matter, your own shadow is a good indicator of ground speed, if you can locate it while high enough for the information to be of any use.

Even if you can't determine wind direction, remember that a crosswind or downwind landing is still much safer than landing in a turn. In fact, one of the more common causes of so called "hook turn" injuries is from unintentional low turns. The scenario is simple: running downwind from a long spot, the pilot doesn't realize until too low they are flying downwind. Then they try to turn into the wind without enough altitude. Most canopies need at least two hundred feet to complete a fast toggle 180 degree turn with a safety margin to spare. Practice turning in half brakes for just this eventuality. A turn in brakes doesn't use nearly as much altitude as a full toggle turn.

Regardless of where you land, you will have a choice of how you approach - either a left or a right hand pattern. Always pick the one that flies over the fewest obstacles and offers the most alternatives. That way, if the wind is stronger than you expected you still have some options.

Common Landing Problems and Their Solutions

Before we look at specific landing problems, here is some general advice. If you have trouble landing your canopy, or you are relatively inexperienced and planning on buying a canopy, have someone your size and weight who really knows what they are doing jump it. They can give you a good idea if the problem is your technique or if it lies in the canopy itself. I also highly recommend video. The common piloting problems discussed below are easily eliminated by one or two video reviews, provided the coach is competent.

Depth perception

We'll get this out of the way at once, since I believe it is the least common problem. Detailed and useful depth perception doesn't occur until we are within fifteen or twenty feet of an object, and in parachute flying this is when we already need to be acting. Furthermore, for novice jumpers there is a timing problem. When your brain finally says "I'm about 15 feet up" it starts an equation based on what would happen if you jump off an object and accelerate constantly till impact OR one based on a steady state descent like the one you are in. It isn't programmed yet for the deceleration you experience as you flare. So depending on your eyes and brain, you might flare high or not flare until too late. This is compounded if there are confusing conditions: twilight, very flat surfaces such as concrete or Astroturf, unusual lighting, tilted surfaces (hillsides), unusual vision (jumping without your usual prescription eyewear), and other eye/brain variables. The only solution I know is experience. Have someone who is real good call the flare for you on several jumps, but only if you are not already flaring correctly. See the other problems below before you put all the blame on depth perception. Usually your brain figures out the depth thing after at most a dozen jumps. Therefore, if you still have trouble flaring it's more likely a technique or equipment problem.

Flaring too high or too low

This is a very common mistake and the way most schools teach a flare only makes it worse. Instructors commonly teach students to make a single flare motion, knowing that a two stage flare is a bit complicated for a first jumper. And since they don't want the student to flare high, they often tell them to flare fast and low. You can get away with this on huge canopies, but it will hurt you when you transition to something requiring more finesse. Flaring is like applying the brakes on a car. It doesn't need to be done all at once, at the last possible moment.

[DIAGRAM UNDER CONSTRUCTION]
Connect the x's from left to right to complete this diagram of what a canopy does in a good flare. The numbers above the line indicate horizontal speed, and the ones below are vertical speed. This is an example only; student canopies fly slower, low aspect ratio and slow canopies have a shorter flat spot in the flare.

This picture is about what a seven cell at 1 to 1 wing loading would do. Many nine cell canopies have a much longer flat spot in the middle. The faster the canopy goes the longer the flat spot in space, though not necessarily in time. From full glide to about a third to half brakes should take a second or two. Then there is a pause as the canopy remains flat and bleeds off speed. Finally, to keep the descent rate slow continue to apply brakes as needed, keeping the angle of attack up and increasing the "flaps" effect for a better slow speed foil (increased camber). Going from full glide to full brakes as fast as possible cuts out the entire middle half of the flare - one second you're flying fine, the next you are at the edge of a stall as airflow separates from the canopy surface. That's why a very fast flare doesn't work well. The canopy needs a smooth transition to flare effectively.

To pick your flare timing imagine a calm day. Put a sheet of blank paper across the drawing to represent the ground. You can easily see that you would rather land towards the end of the flare, where you have the lowest overall speed - a little down, a little forward. Flare too high (move the paper down) and you have a lot of vertical speed. Flare too low (move the paper up) and you have a lot of horizontal speed. Now imagine a day with a ten mile per hour breeze. Move the "ground" up to the optimal point, which is in early part of the second half of the flare - still some forward speed, very little down. This is why 5 to 10 mph days produce the best landings - you have a long sweet spot. But flare too high, and you will be backing up and descending fast. Don't flare enough, or too low, and even though your forward speed is low you still have a lot of downward speed. That's why even on a windy day you need to flare in order to eliminate the downward component. But the windier it gets, the lower you can flare because you only need the first part, the part that flattens you out, not the one that slows you down.

Hopefully this will show why on windy days the common mistake is to flare too high (the other is to undershoot the target, but accuracy is another topic.) On calm days, people tend to flare too low and overshoot. Perhaps this is because our habits aren't based on living in a fluid environment that varies not just day to day but hour to hour. Sailors, kayakers and pilots are used to the idea of life in a fluid and tend to pick this up quickly. People who have led very static lives have a tough time. The bottom line is that you don't need to learn just one flare, you need to learn half a dozen to cover the basic variations in conditions. To do this, you need to combine experience with an understanding of how a parachute flies.

Too much input

This problem occurs when you are indecisive about flare altitude. As a rule "the more you do with your toggles, the harder you land!" Up and down toggle motions cause you to oscillate below the parachute, making it alternately dive and float. This will also reduce lift since airflow is being disrupted. The net result is an increase in descent rate. Your flight path varies constantly, making the situation even more confusing. You land hard. The only way to fix this is to be decisive. If you flare high, stop. Hold what you have, then finish the flare at the appropriate time. This means if you are in half brakes, don't apply the second half at normal flare height, but somewhat lower - say, waist to head high. Finally, it is easier to speed up a flare than slow it down, so when in doubt, maybe wait an extra second.

Asymmetrical or incomplete flare

There are two manifestations of this problem. The first is that the flare stops at about elbow height. Toggle pressure increases as you go down, so the first half is easy but the last requires quite a bit more strength. No problem on a breezy day, but if you come in hot on calm days it may be that you aren't flaring all the way.

The second manifestation is when one hand comes down further than the other. There are two causes. One is having a weak side, and the other is landing crosswind. Fix the first by shifting your beer cans to the left hand (or whichever is the weak side) when discussing your latest crash and burn after jumping is over. You can also develop the habit of turning with your weak side when you are flying around, to get it more used to the toggle feel.

The crosswind is more subtle. Crosswind landings are actually quite easy, but as you flare you need to keep the canopy flying straight, which means a little extra toggle on the upwind side. Like any technique, this can be practiced. But be aware that you should only practice crosswind landings where it won't confuse others in the pattern. You should be the only one landing when you are working on crosswind technique. Naturally, start with a light breeze rather than a strong wind! The main thing to remember is to look where you want to go, not where you are actually going. By doing so you will automatically keep the canopy flying straight and level.

Whether the asymmetrical flare is caused by a weak side or a crosswind, the effect is the same. As the pilot perceives drift to one side, they usually look down where they are going. This turns the canopy even more that way as the hand on the low side comes down and the shoulders rotate that direction. Often the pilot instinctively reaches out for the fall, making it worse - especially if the other hand is forgotten and comes up, a common action. The moral of the story is always look where you want to go, not where you are going. If the canopy is veering left, look straight and compensate with right toggle.

Mechanical problems

A surprising number of canopies come from the factory unevenly built or poorly tuned. Even more slip out of perfect tune after a few hundred jumps. If your canopy has a built in turn, it probably won't flare too well either. Bad line trim can be just an inch of variation, and it takes a good rigger to find this.

Most factory brake settings are wrong. They are built for the average hypothetical perfect wing loading, with no regard to long or short arms, harness configuration, riser length, actual wing loading and other variables. Generally speaking a canopy will have the factory brake mark about three to five inches too low (done so a heavy guy with real long arms can't stall it easily) which means that the last half of the flare can't be completed. While one or two inches of toggle setting might not seem like much, it is very noticeable when landing on a calm day. Therefore, if you routinely come in too fast on calm days this may be your problem. Experiment first with gripping above the toggle to take out a couple inches of line, then with a wrap around your hands. Once you find a setting that gives you a good flare, move the toggles to that point. Be sure to get a rigger or other knowledgeable person to check the toggle attachment. Having a toggle come loose can be a serious emergency, especially if it happens at flare time!

Some people will tell you that if you move your toggles up too far, you reduce the forward speed of the canopy because it is constantly in slight brakes. You also make it fly less well in front risers due to deformation of the foil. But don't worry too much about this. If you get a better flare and don't fly in risers much anyway, what do you care? We are talking good landings, not the CRW nationals, so use what works for you.

Many canopies are just plain dogs, either because of old design and construction or because of wear. F-111 canopies become very permeable and zero-p parachutes lose their line trim. Don't buy old (over 500 jumps) canopies unless you can't afford anything else. If you are in this economic situation, get one bigger than you would if it was new. Generally, don’t assume that your landing problem is pilot error if you are under an old canopy. Check for trim problems and toggle setting. And if you are considering buying a used canopy, get a good pilot of your weight to evaluate it first. Old canopies have a very small zone of forgiveness. If you are looking at one of these, think about what will happen if you step out of that zone. Given the choice, would you prefer to spend money on good gear or medical bills?

Inappropriate transition

If the canopy you are transitioning to is just too different from the one you are used to, you will have trouble figuring it out. That’s why a 120-pound jumper who learns on a Manta might have trouble on a PD 170. The canopy size may be appropriate, but the difference in flight may be too great. Similarly, if you are used to nine cell canopies, going to the short flare and steeper glide of a seven cell can be a bit of a surprise.

Conditions

Wake turbulence or obstacle generated turbulence can suck you into the ground hard. Chase someone’s canopy up high to get a feel for turbulence, but avoid it down low. Density altitude can also deprive you of performance. A rule of thumb is that you lose about three to four percent of performance for every 10 degrees over 70 and/or every thousand feet of elevation. You just don’t notice the loss until faced with a stable reference such as the ground.

Terrain

When landing on a slope, unless there is a lot of wind (10 plus) land across the hill, not up or down hill. It is a good idea to practice crosswind landings for just this sort of eventuality. However, be sure your crosswind training doesn’t confuse or conflict with other traffic!

Finally, there are a couple things to do that will improve your performance even if you already land OK. Cross train: mountain bike, run cross country, ski, kayak, drive - anything involving movement and coordination in a rapidly changing environment. Exercise does a lot more than make you stronger; it makes you mentally more agile. The people who land really well seem to be fairly athletic, so maybe there is a connection. And obviously, if something isn’t working, don’t continue to make the same mistake. In several sports I’ve taught, people seem to intuitively know that repeating a correct action is good, but they don’t always understand that repeating an incorrect action is bad. If you aren’t happy with your landings, something is wrong. Something can be fixed. Do it!

CHAPTER 5: *HIGH SPEED CANOPY FLYING*

During the early nineties advances in materials, design and construction techniques allowed canopy manufacturers to produce a new generation of canopies with previously unheard of durability and speed. Initially these designs were used only by the most advanced skydivers, but in recent years they have become more common among average recreational jumpers. Speed and energy definitely enhance fun potential - but they also greatly increase risk. Unfortunately flying technique, instruction and skydiving customs have not kept up with fast canopies and the sport is paying for it with a big increase in injuries and deaths in which these parachutes are a factor.

Two fundamental truths underlie the risks of fast canopies. One is that kinetic energy increases geometrically with speed. In other words, doubling speed results in a four fold increase in energy. The second is that speed is, essentially, the relationship of distance and time. Doubling speed cuts time or distance in half, leaving a pilot with less time and space in which to consider his options. The bottom line is that using a faster canopy leaves little room for error, while at the same time greatly increasing the penalty for mistakes.

That said, it should still be possible to fly fast parachutes safely. The key is in developing techniques that minimize traffic conflicts and the potential to collide with the ground, obstacles or spectators. Look back at the section in Chapter Three. The sections on obtaining vertical separation are particularly important to anyone planning high speed landings. By minimizing the number of people you share the landing with you minimize your hazards. Furthermore, study the regular jumpers for their tendencies. If you know the flying style of the people you share the sky with it becomes relatively easy to predict their behavior.

The next step is to control the landing area. By this I mean that while still high, you have identified all possible traffic, determined landing direction and considered obstacles and escape routes. I like to do a long crosswind approach since it allows a clear view of the intended landing area and if the crosswind is done over an open area, I can abort the approach to the primary landing area with ease. Never do "S turns" or spirals on the approach if you are sharing the air with other canopies because every turn you make increases the chance of a collision. Unless you are alone, the most predictable and safe pattern is the one airplane pilots use at every airport - downwind, ninety degree turn to crosswind, then ninety degree turn to final.

The Final Turn

Beginning with the first jump course every skydiver is drilled on the concept that a turn close to the ground is one of the leading causes of injury in our sport. Whether such a turn is intentional or not, contact with the ground before the canopy has resumed normal flight often results in serious injury or death. There are essentially two causes of these premature landings. One is an unintentional emergency maneuver, often to avoid a far lesser threat such as a downwind landing. The other is intentionally induced turns.

There is no doubt that the increased speed provided by a turn just prior to landing provides thrilling performance. Since many skydivers seek this particular thrill, they need to be extremely familiar with the effects of turns and the implications of poor judgment. However, even skydivers with no interest in so called "hook turns" still need to know what is involved in order to avoid the consequences of a panic turn. Many of the so-called "hook turn" injuries and fatalities are from unintentional turns. It is also important to distinguish, as we will below, between the out of control hook turn and a controlled high performance landing.

The only safe path to stylish landings is to work your way up slowly, know where to stop, and always be willing to abandon the high performance approach for a more conventional one. For this, of course, you need a canopy that gives this option! One should also recognize that performance is as much a function of piloting as of equipment. Instead of increasing the thrill of canopy flight by moving to a faster design, skydivers should strive to get the maximum performance out of their existing canopy and only move on after they have mastered all aspects of flight on a conservative canopy.

The entry level high performance approach is to use a normal, high toggle turn to put yourself on a straight ahead approach on final, at a comfortable height off the ground. Keeping your toggles securely around your hands, grab your front risers and pull them down about four inches. It will be just like a normal approach, but let the risers up slowly a few feet higher than you would usually flare. Then flare smoothly and slowly at your normal altitude. Initially you will probably initiate and end front riser input too high. Only four or five seconds are needed to reach top speed, so starting too high will wear you out but is otherwise harmless. Ending a little high doesn't do much good either, since your speed bleeds off rapidly. But the important point is that ending high doesn't hurt you either. Ending low will.

There are a few things to watch out for as you begin learning high performance approaches. One is that riser input definitely increases speed. It also increases forward penetration and once you drop the risers your canopy will tend to float. Expect to overshoot your target, so leave some outs! If you have to run out your landings on calm days, either you are flaring too low or your steering lines are out of tune - toggles too low on the lines. Fix this before trying the front riser approach. Finally, whether you choose riser blocks or dive loops, be sure your toggles remain securely in your hands when you grab or release the risers! This should be practiced up high to get the feel of it.

At this point in your progress it is a good idea to have an expert canopy pilot watch a few landings, perhaps with a video camera, and critique your technique. An experienced eye can tell you if you are using too much front riser, if your toggles need to be re-set, if you are flaring unevenly, and other important details.

Once you are to the point where you never under or over shoot your landing or have to alter your approach because of traffic not accounted for early enough, you may want to use a slight front riser turn onto your final approach. Be an honest judge of your performance: if you use variables such as changing winds, traffic, or other conditions to excuse a botched approach, you have not mastered the first two steps: traffic management and control of the landing area environment. Using excuses indicates an unwillingness to take responsibility for inexperience or poor judgment, a mental state that has no business in the world of high speed canopies. The increased speed created by high performance canopy flying is a great hazard to others in the landing area, and therefore carries a heavy weight of responsibility. Under a fast canopy there are no excuses!

Progress by making shallow front riser turns of about 30 to 45 degrees onto your final approach, then transition to both front risers until flare time. A turning front riser approach is a step beyond a straight approach, and probably the most commonly used high performance approach. As with a straight approach, a good front riser turn requires a smooth entry and exit from the maneuver. The initiation of the turn may be steep, but the second half should have a gradual reduction in front riser input. In this situation, the initial steep descent creates speed that is translated into lift as the parachute flattens out. The transition from riser input to toggles should be almost imperceptible.

If at any time you are having to use rapid, aggressive toggle movement to avoid hitting the ground, you are far too low in your turn. "Stabbing" the toggles down is a definite indication of poor control. The best landings involve both a gradual entry and exit from front risers, followed by a smooth, slow flare. A well landed canopy builds speed gradually and practically flares itself as front risers are smoothly released, leaving the pilot to slowly bring the toggles down to keep the canopy planing as it bleeds off speed. Not only does stabbing the toggles indicate the pilot was about to hit the ground hard, it deteriorates the overall landing. Why? Because toggles are also brakes. The less you use them, the further and faster you will be able to swoop. The longest, fastest canopy swoopers always use the least amount of toggle input!

Because of the lack of formal training for high performance landings, many skydivers have developed bad flying habits that put them in dangerous or inefficient situations without conferring any speed and performance benefits. For example, if too much front riser is pulled down, you deform the airfoil and reduce its efficiency. This will become obvious when you realize pulling the front risers down only affects the front area of the canopy. Seen from the side a canopy with too much front riser input appears to have a step in it, which means a perfectly good canopy has been deformed to the point where it no longer flies well. The classic manifestation of the trashed foil is a canopy that appears to be bucking, or lurching down a flight of stairs. In some situations (and only with some canopies!) this is actually useful, such as initial descent into a tight area like a clearing in the woods or a stadium. For landings, however, deep front risers need to be released early since they create lots of downward speed but not much lift.

Another common mistake in front riser approaches is to enter and exit the front riser maneuver suddenly. A sudden change of the surface configuration can disrupt the smoothness of the flow and cause a dramatic loss of lift! Suddenly dropping the front risers and then rapidly braking with toggles is a very inefficient way to flare, since both actions handicap the airfoil’s lifting ability. Instead, a good front riser landing involves a gentle entry into front risers (never let go of your toggles!) that gradually steepens until the canopy achieves its fastest speed without major distortion of the wing. When the risers are smoothly let up, the canopy slows down and the pilot swings forward - the flare has begun before the toggles are even used. Then, the pilot maintains the high angle of attack by using toggle input to keep the flare going.

In any discussion of high performance landings the subject of riser verses toggle turns will come up. After years of watching a variety of techniques, I have concluded that front riser turns are far superior to toggle turns from a safety stand point. The reason is an extremely simple one. For a toggle turn to produce any speed to swoop with, it must be done as low as possible! Otherwise, it is just another high turn and all of the speed bleeds off well before the flare. A front riser turn, on the other hand, can intentionally be initiated too high, and then steepened or supplemented with the other front riser as needed. Therefore, a swooper using a front riser approach can always start at a conservative height while a toggle turn onto final compels the skydiver to turn as low as possible.

The implication of this goes further because of the way a canopy comes out of a turn. A front riser turn accelerates the canopy, while a toggle turn slows the canopy down. The difference is most noticeable at the end of the turn. Following a front riser maneuver, the canopy slows down to its normal speed and wants to come back over the pilot. After a toggle turn, the canopy must speed up, then there is a considerable delay before the pilot swings back under it. A toggle turn may create a bigger pendulum action for the suspended weight because the canopy can slow down much faster than the person under it, whereas in a riser turn the canopy accelerates only slightly faster than the pilot. In a toggle turn, the pilot must swing back under the parachute and the parachute must regain lost speed before it is controllable and generating maximum lift.

A front riser turn is easily abandoned at any point, with full control of the canopy retained. Once a toggle turn is in effect, there is no escape.

A dramatic toggle turn also causes the wing loading of the canopy to change considerably - normal in flight, low as the canopy slows down and the weight reaches the height of its swing, then heavy as the weight swings back under the canopy. Whether or not these dynamic changes in wing loading make the canopy more vulnerable to turbulence than the fairly steady loading of a riser turn is open to debate.

An additional hazard with toggle turns can occur at very high wing loadings - perhaps 1.4 or higher, depending on the canopy. In a sharp enough turn, the pilot can swing out so far that as he swings back under the canopy, the induced weight overloads the canopy. In this situation the wing is essentially in a high speed stall - what pilots would call an accelerated stall. At this point the pilot has no control and even flaring may be useless. In fact, flaring might reduce lift even further. In any case, remember the apparent wind. If you are looking straight at the ground, flaring will only change your impact point.

However, this is not a blanket endorsement of front riser turns. There is a phenomenon that can take place in a high speed turn that can lead to complete collapse of the canopy, and in theory a canopy in a sudden front riser turn may be the most susceptible. Canopy collapse takes place when the apparent wind striking a canopy undergoes a sudden change, whether the cause be a change in angle of attack, angle of incidence, or some other factor - wake turbulence off another canopy, for example - causes the canopy to be "back winded," a term from sailing. When a foil is back winded, it means the apparent wind is striking the lifting surface of the foil instead of the leading edge. In the case of a canopy, this can drive the air out of the cells and collapse the canopy. Canopies at particular risk are small, highly loaded canopies with a relatively flat trim angle and a relatively aft center of lift. Proponents of toggle turns argue that a front riser turn is more likely than a toggle turn to produce a canopy collapse, due to the changing angle of incidence. In the real world, the few catastrophic canopy collapses on record seem to be more a factor of design than of handling. There does not seen to be a correlation between front riser input and canopy collapse - at least none that I know of.

In summary, while both front riser turns and toggle turns create an increased descent rate and corresponding increase in speed, for intentional maneuvers a front riser turn is usually more desirable in that it offers more escapes in the event of a lapse of judgment or a sudden change in the environment.

Turns over 90 degrees carry an unacceptable degree of risk to other skydivers unless they are very carefully executed within an established pattern. It becomes very difficult to monitor traffic once you stray from the customary downwind, crosswind, final pattern. Equally important, it is difficult for traffic to monitor you! Downwind legs over the landing area followed by low 180s not only create tremendous changes in vertical and horizontal speeds but interfere with the traffic patterns already established by others. An additional consideration is that a turn over 90 degrees does not confer significant increases in speed but greatly increases the potential for mistakes, not just on the part of the person doing the hook turn. Some of the other parachutes on approach could be piloted by people who may not be able to avoid unusual wake turbulence or who might do their own low turn unintentionally in order to avoid the undisciplined canopy pilot. The same ethics apply to people on the ground. The whuffo being swooped could be deaf or unaware of how parachutes fly, and no skydiver likes to hear the whistle of wind through microline behind their back and wonder if they are the next innocent victim.

Referring again to practical tests with an airspeed indicator and variometer, modern canopies at 1.4 wing loadings typically fly at about 30 mph straight and level, toggles up. They can hit speeds of up to 50 mph coming out of a turn, and may be going 20 mph with the brakes still set for deployment. In descent rate modern canopies usually peg my variometer at its peak reading of 1600 feet per minute of descent, giving us a minimum downward component of 18 miles per hour. Since this instrument limit is hit long before the maneuver is completed, we can assume downward speeds of 20 to 30 mph are routine when deep in a turn. Older, lightly loaded designs are significantly slower. Thus, it is the combination of a fast canopy, high wing loading and a turning maneuver that creates the greatest energy.

Besides the amount of kinetic energy delivered by fast canopies, there is the time factor. I prefer to use feet per second instead of miles per hour, since skydivers work in feet and seconds, not miles and hours. Twenty miles per hour is roughly 30 feet per second. Thirty miles per hour is roughly 45 feet per second, and fifty miles per hour is about 75 feet per second. Regardless of how fast the canopy flies, human reaction time is about one quarter of a second to merely recognize a problem. In a complex emergency situation, we can assume that an alert individual will require a quarter second to recognize a problem and no less than the remainder of a second to implement a response.

A second is more than enough time to resolve a simple emergency- pulling your hand away from a hot stove, for example - but is it enough time to recognize, assess and resolve a potential canopy collision? I think not, since the pilot must not only avoid the collis ion but do it in such a way that he does not create an equally serious secondary emergency, such as a different collision.

The illustration shows [webmaster's note: we're still working on the illustrations] two canopies on a collision course at ninety degrees to one another. We can see that in situation a) the canopies are one second from a collision when they are 42.4 feet apart. If we speed the canopies up, that one second remains constant as the distance expands. In situation C, the canopies are one second from collision when they are just over one hundred feet apart.

Now imagine that these scenarios are transpiring not on a blank sheet of paper but in a crowded sky fifty feet above the ground. Add a couple buildings and some power lines to the landing area to dramatically curtail the options. The point? We must assume a single second is not enough time to adequately respond to this complex emergency. That means to have any kind of safety margin - let’s say three seconds - the canopy pilots in situation C must know the position, current direction and the intent of every canopy within three hundred feet.

In a similar situation, let’s substitute a running child (12 feet per second) for one of the canopies. If the child darts out in front of the swooper (canopy C) with only 40 feet of horizontal separation, we have a dead child on our hands.

Using the same scenarios and assuming a collision at the end, let’s look at the kinetic energy involved. For simplicity we will assume that the skydivers involved both weigh 170 pounds. Using mass times velocity squared to determine the energy going into the collision, we find each skydiver in a) enters the game with 153,000 foot-pounds of energy, for a total collision force of 306,000. Moving to scene c) we come up with 956,250 per skydiver and 1,912,500 total points in the collision.

Substitute a seventy pound child at 12 feet per second for one of the canopies, and you find the child enters collision a) with a mere 10,080 points versus the skydiver with 153,000. In c) the difference is even more spectacular: 10,080 vs. 956,250.

Thus we see that speed, more than any other factor, drives up risk by increasing collision forces and reducing the time and space in which we act. An interesting corollary develops with fast canopies; piloting them to a safe landing can demand so much focus that other important factors might be neglected. For example, if you need to devote all of your concentration to your canopy handling in order to land well, you have nothing left for traffic management. Conversely, if a traffic problem suddenly arises you may not have enough attention left to land your own parachute well. In a crowded landing area with canopies of varying speeds you need to devote quite a bit of concentration to the other canopies. If your own parachute demands all of your attention, you cannot safely land around others.