CANOPY FORMATION PARACHUTING - CF

Basics for Beginners, Teams and Trainers

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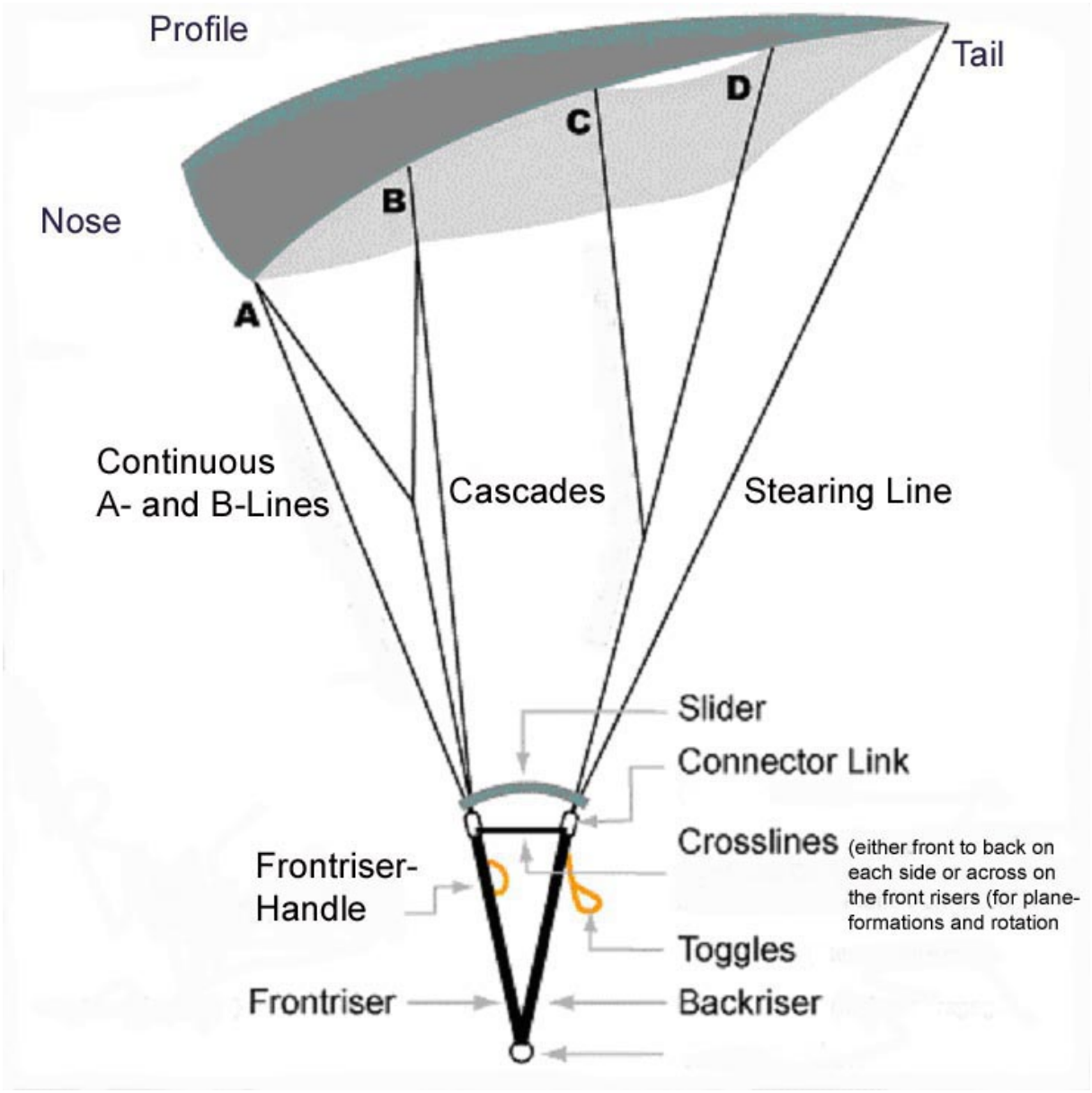
0. Introduction

In the early days of CReW as canopy formation skydiving used to be called in those days I wrote and published a little booklet in for those who were interested to learn the new sport. That was in the early eighties. Things have changed a lot since then. So I found it necessary to publish something new to make general information on our sport available to everybody interested. This new essay combines techniques and hints form Europe and America. The latest input came from the training camps for the new canopy formation world record attempts aiming for a 100-way formation. This paper will be continued and I invite everybody to give me input to improve and complete this paper.

1.1 Canopy and Harness

The best parachutes for canopy formation parachuting (further briefly called **„CF“**, in the old days also called CRW) are 7-cell canopies. These parachutes are the safest concerning deployment and stability in flight, especially in turbulent conditions. It is no coincidence that reserve parachutes and canopies for BASE jumping are mostly 7-cell canopies.
The times are gone where they had all round canopies that could be used fairly well for any kind of skydive. Such canopies were for instance: Cruisair, Unit, Pegasus, Cruislite and Fury to name only a few. Triathlons and Spectres with Dacron lines can be used for casual CF jumps, although Lightnings are the CF canopies of choice.
If you intend to do a CF jump today you are well advised to use a canopy that has been designed for this kind of activity.
As a compromise for your first attempts you may use a 7-cell canopy with a thick profile for instance a student or accuracy canopy. Never attempt CF jumps with elliptical canopies, canopies with wide wing span (fairly wide in comparison with the depth of the profile / length in direction of flight) and/or a low profile.



Today's CF canopies are available in different sizes made for different weight classes of jumpers. It is important that people intending to join a CF jump use the same type of canopy with the same line length and trim. Further more the wing loading (weight under canopy per square foot) should be about the same to guarantee similar flight characteristics.

The container of your harness should be big enough for the packing volume of your canopy to make sure it can be closed properly (safety!). There should be no handles, container flaps, pop top pilot chutes etc. sticking out that could get caught in other jumper's lines. Those things could result in unintentional reserve openings or problems on separation.
Also should the bridle be short or even better self retracting to prevent your pilot chute from being caught in the other jumper's lines while you are in a plane formation for example. You can imagine that separating a plane formation with one jumpers pilot chute entangled in the other jumper's lines will most certainly result in serious problems.

1.2 Additional Equipment

The altimeter should be worn in a way that makes sure it does not get snagged and can always be seen while you have your hands in the toggles.

The helmet should provide not only head protection but also allow good hearing. It should not cause wind noise that might affect your hearing.

Every CF jumper should carry a hook knife that can be used in case of an entanglement or wrap. Sometimes it only takes one line to be cut to get free and save a reserve ride.

The hook knife of course should also be worn in a way that prevents it from being caught or ripped away.

Your shoes must not have any hooks. They should fit loose enough that you can get rid of them if need be in order to get free.

It is very useful to wear long socks to protect your legs against bruises and line burns.

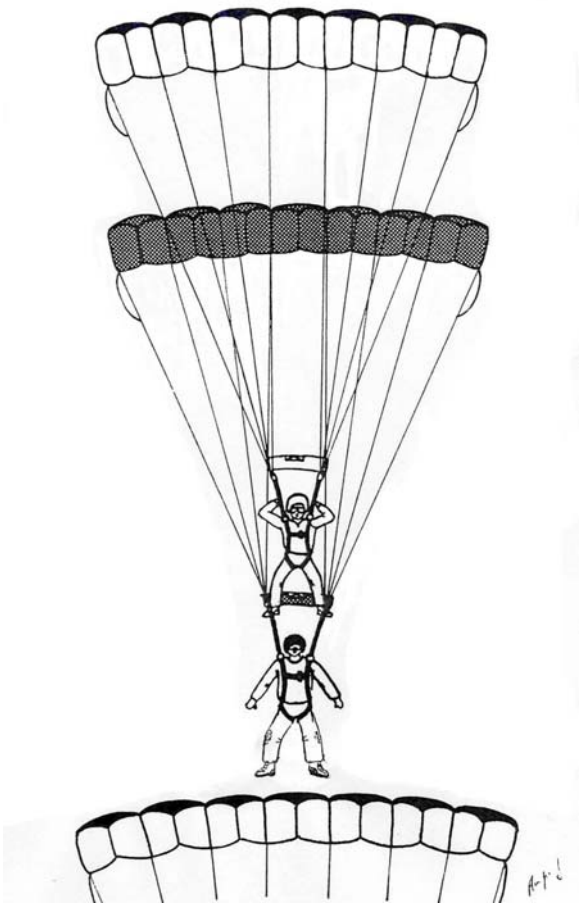
2. FORMATION TYPS

2.1 STACK

The stack is the basic formation. To make a stack one jumper sits on top the other jumpers center cell and hooks his feet behind the center A-lines of the lower canopy like somebody who sits on a chair in a similar way.

Ther will be some tension on the lines because the lower canopy in this type of formation will have a little less lift as we will se later on.

2.2 PLANE



The plane is created out of the stack. The top jumper climbs down the center A-lines and hooks his feet behind the front risers of the lower jumper underneath the slider. The lower jumper supports him by putting on some brakes to increase the lift of his canopy. For this formation type one or two cross connectors are required that either connect the front connector links (one line) or two lines that connect the front and rear connector link on either side. Otherwise the top jumper might slide back up due to his plus of lift and pull up the slider witch would result in a collapsed lower canopy.

2.3 STAIRSTEP

In a stairstep formation the top jumper is positioned outside of the lower canopies end cell. He takes a foot grip on the outside A-line .

Flying the stair step requires much more experience than flying a stack or plane formation because the link is not as stable. It is more of a pivot point than a stable connection.

The lower jumper has to compensate for the influence of the upper jumper's body to the flight of his canopy. To prevent the lower canopy from coming up and around you can put some tension on the outside front riser of the lower canopy or the lower jumper can stretch the outside leg while lifting the inside leg.

3. AERODYNAMICS

3.1 Aerodynamics of the Airfoil

Lift is the force that keeps your canopy in the air. In opposition to the round canopy that only creates a big air resistance to slow down your descent using a large area of fabric the square parachute or airfoil really produces lift like the wing of a glider for instance. The square footage of an airfoil is only about the sixth to a quarter of a round canopy and has a far lower rate of descent.

The lift of the airfoil consists of 1/3 high pressure under the profile (similar to the round canopy) and 2/3 low pressure on the top surface created by the undisturbed airflow. This effect is the important matter for us.

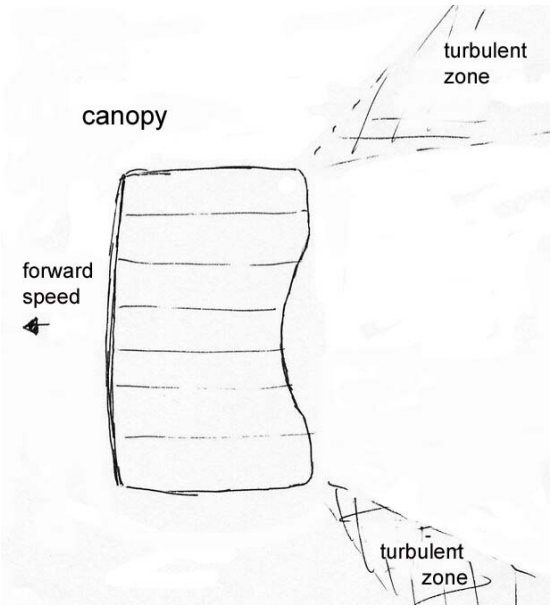
The physical reasons for this effect don't really matter here. Most important is to know that the main part of the lift depends on the undisturbed airflow on the top surface of the square canopy, its forward speed and the shape of the profile. The lift gets bigger with the forward speed and grows with the thickness of the profile. The air resistance of the canopy slows the forward speed down.

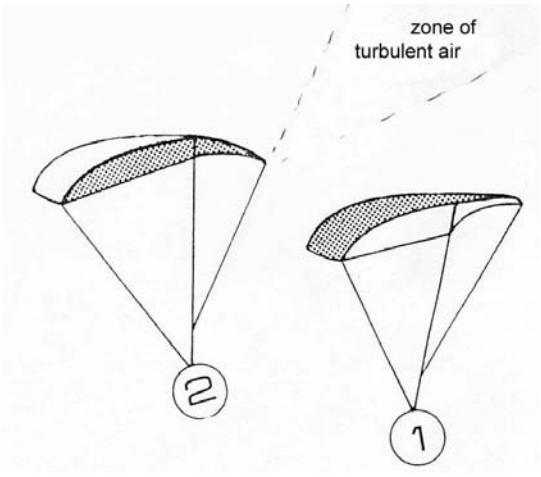
Due to the different pressure at the upper and lower surface of the profile air will flow around the sides of the canopy from the bottom to the top following the pressure difference. This effect reduces the lift and is called induced resistance. As a consequence of this the maximum lift is in the centre of the airfoil. The stabilizers on either side of the profile are designed to reduce the loss of lift by hindering the airflow from the bottom to the top surface. Another way to reduce the loss of lift is to make the airfoil very wide so that the percentage of wing area being affected becomes comparably small. A good sample for this solution is the paraglider. This shape of airfoil is of course not good for CF activities.

Because of the airflow around the sides and also around the tail of the airfoil a parachute gliding through the air leaves a track of turbulence. The side turbulence creates a zone of turbulent air on either side beginning at the trailing corners of the airfoil and the turbulence of the tail a turbulent zone rising from the trailing edge of the canopy.

It is clear that a parachute or canopy formation flying into such a turbulent zone will be affected by losing lift. Even aircraft flying through the turbulence of a canopy formation will lose considerable altitude.

The following pictures are showing the shape and position of the zones of turbulence.





3.2 Aerodynamics in the Formation

In a formation these phenomenon cause effects that can be noticed clearly. Just the top canopy in a formation gets only undisturbed airflow and has the maximum possible lift.

All canopies having a body in front or on a front corner will lose lift due to the turbulence caused by the body out in front.

3.3 Aerodynamics of the basic Formation Types

Knowing the things said above you can predict that any type of formation cannot perform as well as a single canopy. That is useful for building formations as it gives the single canopy the potential to approach and dock on a formation due to its extra lift and forward speed.

In principle all formations consist of the basic types already mentioned in chapter 2. For this reason we are going to look at the conditions in these basic formations.

3.3.1 Aerodynamics of the Stack

In a stack the body of the top jumper is in front of the center cell of the lower canopy. The turbulence of that body meet the airflow of the lower canopy exactly where the main lift is created an leads to a considerable loss. That means that a stack will sink far more than a single canopy.

3.3.2 Aerodynamics of the Plane

In a plane formation this effect is not as strong. As the top jumper's body is below the two canopies you might think there is no loss of lift at all but the line contact causes a deformation of the lower canopy and also forces both canopies into a new aspect ratio witch leads to a loss of performance. You will find a single canopy performing better than a biplane.

If a plane becomes bigger there will of course be canopies with bodies in front of them. Planes with more than four canopies will sink faster the bigger they get.

3.3.3 Aerodynamics of the Stairstep

The stair-step is far better off. The body of the top jumper only causes turbulence on the outside corner of the lower canopy and that is a part of the airfoil that only contributes a minor part of the lift. That means that a stair step formation is performing only little worse than the single canopy.

Because only one side of the lower canopy is affected the other side will perform better and make the canopy rise and drive forward. If the lower jumper does not compensate this his canopy might come up and around leading to a wrap. To prevent that the lower jumper will start to compensate for the difference in performance of the sides of his canopy as soon as the top jumper has taken his grip. Possible ways to do so are: putting tension on the outside front riser, stretching the outside leg while lifting the inside leg, and possibly applying some slight inside brake. You can try out how much trim is needed by easing up after you have set your canopy. Sometimes the formation will keep flying well with only little trim or none at all. Never the less the lower jumper should keep a watchful eye on his canopy to compensate immediately if necessary.

4. TECHNIQUES

4.1 Packing the Canopy

You will want to pack your canopy for a CF jump in a way which will ensure that:
- first, it opens fast and reliably
- second, it opens on heading
- third, all canopies involved open with the same timing

A good way to achieve this is to pack it similar to a reserve canopy as the requirements for a reserve opening are about the same. Indeed many CF teams do so. Since there are different methods of reserve packing it is recommended that all jumpers involved in a team or group should use the same packing method for safety reasons. That reduces the probability of collisions and unintended different opening levels to make sure that everybody has an optimal set up for his way to the formation.

4.2 Type of Exit and Exit Order

A good exit speed is 70 to 80 knots with little prop blast. For the beginning it will do if the jumpers exit one after another in a way that students do performing a “hop and pop” and remain stable. It is essential to remain in a symmetrical body position until the canopy is completely inflated to make sure that it opens on heading and keeps flying straight until you want to fly your pattern towards the docking position. The tighter the exit becomes the more important this is.

If your canopy does not open on heading you can easily end up in a dangerous collision or at least in a bad position for your approach towards the formation. Also other jumpers can be disturbed by trying to avoid you.

In general you will exit in the order of your position in the formation. Competition teams may use different techniques to speed up the build of their first formation.

4.3 Timing

Teams with more experience will start do develop an exit with two or three jumpers standing in the door jumping with only very little delay one after another and pulling in sequence to get a perfect set up for the built of their first point out of the exit. In this type of exit the last jumper leaving the plane (front person in the door) pulls first. The next jumper pulls when he can see the beginning deployment of the jumper above. This leads to a set up with the lower canopy slightly in front which means a perfect set up for a final approach.

4.4 Set-Up for Building the Formation

In most cases it makes sense if the Base jumper sets up on heading, flying with a little brakes, slightly lower than the jumpers that are to dock next. That gives the following jumpers the potential to fly to their docking position because altitude is our fuel.
A good position for the final approach of a single canopy is slightly higher and to the side (maybe slightly behind) of the canopy to dock, onflying parallel with it.
The optimum setup of course depends on the flight characteristics of the formation to dock on.
For docking on a fast sinking formation you will certainly want to set up lower than for docking on a floaty formation. The necessary experience to estimate the perfect set up will only come with the jumper and quality of your jumps

4.5 Body Position

To keep your canopy flying straight with even controls your body position has to be symmetrical. Your shoulders should be square and your arms in a “box position” and your legs slightly spread and bent as shown in the sketch of a stack. If you lift one leg from that position while stretching the other one your canopy will start to turn towards the stretched leg. If done on purpose this can be a useful tool as for instance in a stair step formation. Bent legs also give you a certain potential to compensate tensions in a formation and to dampen oscillations.

4.6 Reducing Altitude

If you get close to the setup position for your final approach to the formation you might find yourself higher than desired (if your are too low or far behind you are lost anyways).
There are different ways to lose extra altitude without using much space. It always makes sense to stay in a small area because first, long distance movements take much more time and second, you might interfere with the waiting position of another jumper.
Furthermore you might have difficulties to estimate your exact position.

4.6.1 Sashay

About the oldest technique to lose altitude is the sashey. It has been used in 4 way rotations. The sashay begins with a radical toggle turn away from the formation then and a reverse movement as soon as the canopy has tilted to the side and is stopped out with both toggles. It is not very efficient utilizing a lot of area and you may lose track of your position relative to the formation. It takes a lot of practice to get good results with this radical maneuver.

4.6.2 Over the Top

Also from rotations comes the “rotation over the top“. The move begins with putting on deep brakes quickly. As soon as the canopy rocks back you grab both front risers and pull them down radically without letting go of your toggles. It takes less force than you might expect because if done at the right moment you meet the canopy having almost no lift and no tension on the lines. Now you riser down little further than your final destination release the risers and swoop into your docking position by using the toggles.
Today some successful teams are using a combination of the two techniques mentioned so far. But that is a different story and will be explained another time. It is only important for rotation teams that have already reached a high skill level and still want to improve.

4.6.3 Cross Controls

If it is important to use very little space you can easily lose altitude by using cross controls. That means you pull down one front riser, then compensate the move your canopy would now make by applying the toggle on the opposite side. Because the canopy is being distorted it sinks and would pick up speed to the distorted side. The toggle action evens out this momentum so that the canopy ends up sinking in place assuming that you find the right balance of controls. Doing so you can get into the desired set up position for your final approach without disturbing another jumper in his set up position close to the formation.

4.6.4 Rear Riser Stall

A similar result can be achieved by performing a rear riser stall. To do so you grab the connector links on your rear risers and pull them down carefully. You will notice that this is not very hard to do. That is because the main part of the lift is being created in the first third of the profile where the A- and B-lines are attached to the front risers.

At first your canopy will start to glide flatter without losing much speed. This range can be useful if you find yourself far away from the drop zone on a down wind flight pattern and want to get as close to the DZ as possible. If you pull the risers down a little further the canopy will smoothly start to stall and sink very fast. This technique can help to lose a lot of altitude. However it should be practiced with only two jumpers involved before being used in a big way jump. It is not recommended in a tight echelon because your canopy might come out of that stall bailing out to the side and interfere with other jumpers in line.

4.6.5 Rear Riser

If you are too low and need to gain potential for instance on the way to your waiting position or if you got behind the formation you can use very light pressure on both rear risers to fly a fatter path without loosing much forward speed. This has to be done very carefully because it you pull them down too much you will lose speed and only millimeters further end up in the rear riser stall.

4.7 Techniques for Approaches

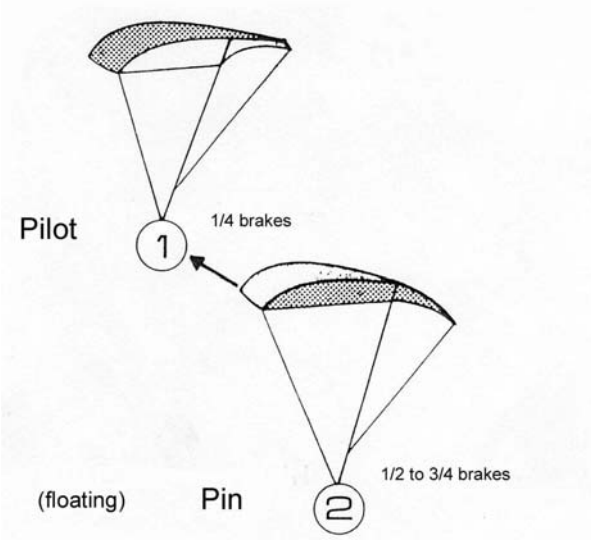
The most challenging part of a CF jump is the build of the initial 2 way formation or the dock on a single canopy. A formation as we have learned before will usually not perform as well as a single parachute. Docking on a formation always gives you a little extra performance relative to the formation since you have a single canopy with all of its lift. You will need good technique(s) to dock a single parachute with similar performance.
That means you need to gain some momentum when attempting to dock on a canopy flying by itself. The only way to do so is by setting up higher and not too far behind.
The canopy to be docked upon should hold a little brakes to make things easier.
The docking jumper begins his approach setting from a position with his feet about the level of the canopy he's docking on, slightly behind or a little to the side. The approach is to be initiated by using the front risers to pick up speed and controlling the direction of flight. Now you pilot your canopy to a position slightly lower and slightly behind the final docking point. The final move is done with the toggles reducing speed, swooping up to the desired level and aiming the docking cell to the desired position (center cell for a stack or end cell for a stair step). It is essential not to have too much energy left when docking and also not to end up too low. If you end up too low the dock is completely spoiled. If you have a little left over energy that can be handled with some experience. If you find yourself having too much left over energy you should abort the dock for safety reasons and use the potential energy to fly to a good position for a new setup and another attempt.

4.8 Building the basic Formations

In principle there are only two or three ways of making approaches.

4.8.5 Building a Stack

To build a stack the jumper who is docking sets up slightly behind and above the canopy he's docking on while the jumper to be docked upon flies straight holding a little brakes, as explained in 4.7 He stays in brakes until the docking center cell has touched his back. If the dock is perfect and he has some experience he can take foot grips hooking his feet behind the center lines. If not he can release his toggles grab the docking canopies nose get it into the right position and then take the foot grips. Having done so he gets back on the toggles to control the formation. Never release your toggles before the docking canopy has actually touched you because if you do your own canopy picks up speed and flies away from the canopy trying to dock.
In any case it is important that he releases both toggles evenly to prevent the formation from spiraling.
It is also very important that the docking pilot can see at least the lower legs of the jumper he's docking on. Should the legs become shorter and shorter you need to add more brakes. It an absolute NO to pass under a jumper you intended to dock on. If you have the impression that this is about to happen you must abort the attempted approach by either stalling radically or turn away with one front riser pulled down. It can be extremely dangerous to fly underneath and in front of a formation because your burbles can cause canopies in the formation to collapse. Also you could lift up with the middle of your canopy under the jumper you wanted to dock on ending up in a wrap. That means if you perform any kind of dock on a formation you have to be in full control of your canopy at all times and able to abort if not. Otherwise you are not qualified to do CF jumps.



Final approach to a stack

If the docking canopy ends up higher than wanted that is not necessarily a problem. The docking jumper can park his canopy with his nose in the center against the lines of the top canopy and slide it down by using his front risers moderately until the top jumper is able to reach for his grips.
Approaches to lower positions in a stack or plane will need a lower set up than for high positions because the formation begins to sink more with its size - especially the plane.
Speed teams many want to dock the position three and four still from a high position and perform a riser dock by aiming their slider to the jumpers feet to dock on instead of the center cell.

4.8.6 Building a Plane

To build a plane you start with a stack. Then the top jumper starts to climb down the center A-lines and having reached the slider he now hooks his feet behind the front risers of the lower jumper. The lower jumper helps by putting on some brakes to increase the lift of his canopy. If the top jumper needs to pull himself down on the A-lines he has to do so evenly to prevent the formation from oscillating sideways.

4.8.7 Building a Stairstep

The Stairstep is the second basic type of formation. The technique for a stairstep dock is similar to the techniques explained before but because the Stairstep is far less solid than a stack or plane everything has to be done softer and with more precision.
The set up for the final approach is a little to the side of the formation. To make a clean straight and precise dock you want to keep it relatively short with not too much potential. You may start with one canopy width to the side of your target canopy and your canopy slightly lower than the canopy to dock. The approach should be from the side rather than from behind so that the jumper to be docked upon has a good view of the line he wants to catch as well as remaining in the clean air to the side of the docking canopy. Also in this type of dock you should never get too low or lose sight of the target. The docking end cell should end up at the hip to the shoulder of the docked body. The docked jumper can now hook his outside foot behind the outside A-line of the docking canopy with his body staying outside the docking cell. If the grip taker should need to use a hand grip to guide the docking canopy to a good position for taking ther foot grip he has to be well aware to maintain his body position in the harness to prevent unwanted influence on the flight of his own canopy.
The docking pilot puts on some outside front riser trim as soon as the top jumper has taken his grip to prevent his canopy from coming up on the opposite side. After having set his canopy by doing so he may release some of that trim or maybe even all of it. Sometimes it gives you enough trim to stretch the outside leg to keep the bottom canopy flying nicely. Sometimes no further trim is needed any more but still you should keep your hand on the outside front riser ready to apply trim again if needed.
The set up for stairstep docks in lower positions may be somewhat lower. None-theless be aware that a stairstep formation flies fast and flat compared to other formation types. If your setup is too low your docking time may become very long.

The build of the stairstep, stack, or plane can of course also be done in reverse order with the lower canopy flying in little brakes and being the target and the top canopy flying the approach. The technique is referred to as the **Top-Dock** and will be explained with techniques of sequential CF later on.

4.9 Flying in the Formation

As in free fall skydiving you have to keep on flying after you docked. In a stack for instance, especially in the bottom position, you need to make sure that your canopy does not get too light and floats up. All canopies should have slight tension on the center A-line to make the formation healthy.
In a plane it is important that all cells of all canopies are inflated. If not the jumper in question can reinflate his closed cells by putting on some brakes. Perhaps he will also have to maintain some toggle trim to keep his canopy's nose open. Also a jumper next to a closed cell can help by pulling the nose open.
Good awareness is needed in formations with stairstep grips like stairsteps, diamonds or boxes. Especially jumpers in lower positions need to always keep their canopies from coming up or around. Possible techniques are: outside front riser trim asymmetrical leg position and inside toggle.

4.10 Signals within the Formation

To signal information to other jumpers in the formation there are two ways. You can either shout a command by addressing the jumper with his name or use certain signs. In bigger formations it is more convenient in most cases to use signals instead of vocal communication to avoid noise and confusion. The signs and commands to use must be known well to everybody. In case of vocal information you must never use negative commands. If for instance you shout "don't cut away!" and the other jumper misunderstands he will cut away. In this case you should have said "hold on!" for example.
In large formations there are two very useful signals to the jumper below you: Twisting your foot sideways means the jumper whose canopy is on that foot needs to get lighter for example by putting on some brakes or easing the front riser pressure if possible.
Shaking the foot vertically means get heavy which means put on some front riser pressure or signal further down if the jumper(s) below is (are) light on you as well.

4.11 Piloting a Formation

Stack and plane formations always follow the top canopy and are controlled by the top jumper also called the pilot. The stair step needs more caution than the stack because it is connected less stable. Diamond formations act similar but in bigger formations the pilot might need some assistance by all the out side wing people to help keep the formation flying straight or to help turn the formation. Bigger diamonds are fairly inert. It takes some time to make a big diamond turn.
The most attention is needed in stair steps. In a turning stair step the bottom jumper always needs to compensate the change in the flight characteristic of the turning stair step versus the straight flying one. If the formation is turning away from him he needs to release some of his outside front riser trim and if the formation turns towards him he needs to increase the trim on his outside riser. Because the links in a

stairstep formation are similar to pivot points these formations need to be turned very carefully.

4.12 Separating a Formation

Separating a formation needs at least as much attention as building one, especially for safety reasons. Also should it be done high enough. Bigger formations should be separated at 1.500m (5.000ft) and smaller ones at 900m (3.000ft).

Small formations can be split in reverse order of building letting go one jumper after another. The jumper whose turn it is to go shouts the names of the ones holding him and they drop him. Then he clears the proximity of the formation immediately to give room for the next jumper to leave it.

Larger formations in the shape of a diamond of up to 36 jumpers can be split by using a technique called STARBURST. The starburst is being started by the designated person calling “starburst! - starburst!” which is to be echoed through the formation. Then one person starts a count down calling “ok – ten, nine.....two, one, break!“ Everybody else joins the count loudly to make sure that everybody is able to hear it. On “one” everybody get his hands on the controls and on break lets go of the grips to fly out of the formation radially away from the center.

4.13 Landing a Formation

Smaller Formations can be landed. It is not recommended to land formations bigger than four.

To be continued.....

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