The relation of Stability and Maneuverability in Skydiving

by Vladimir Milosavljevic & Tamara Koyn

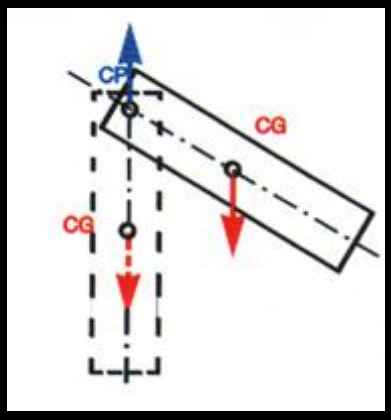
The basic principles of stability in skydiving have been addressed. However, the connection between stability and maneuverability deserves more coverage. Understanding and utilizing the relationship of stability and maneuverability in skydiving marks a transition into more advanced skydiving techniques and thus an important "key" to the advancement of skydiving as a sport

Stability and Maneuverability

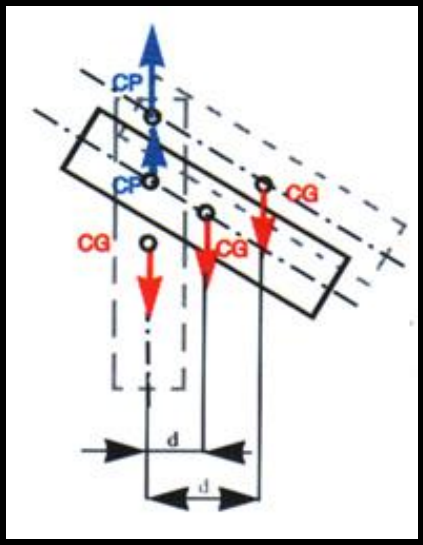
Stability itself is defined as a body's tendency to return to its original state of equilibrium on its own, after a force is exerted upon it. When a body is unstable, it will tend to move away from its original position, when a force is applied.

Stability and maneuverability exist very much opposite of one another! In other words, while freefalling in a more stable body position (with all other factors equal), you will not be able to maneuver as quickly. If you fly in a less stable position, you will be able to maneuver faster!

To further explore this theory, we need to review a few concepts relating to a body's existence and behavior in free fall. At terminal velocity, the body is exposed to relative wind that opposes the pull of gravity and causes the body to fall at a constant rate. In other words, at terminal velocity, the body is supported by a force of drag. That support from drag can be said to be acting on the single point of the body. This is the "hanging point". In aerodynamics, this point at which we can assume that all the aerodynamic forces are concentrated is defined as the center of pressure (CP). For the purposes of this discussion, we call it the "hanging point".

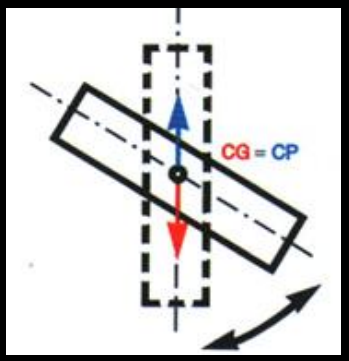


If the "hanging point" is above the center of gravity, a body will be stable. That means, if we try to displace such body, it will resist displacement and will try to stabilize again in its original position.

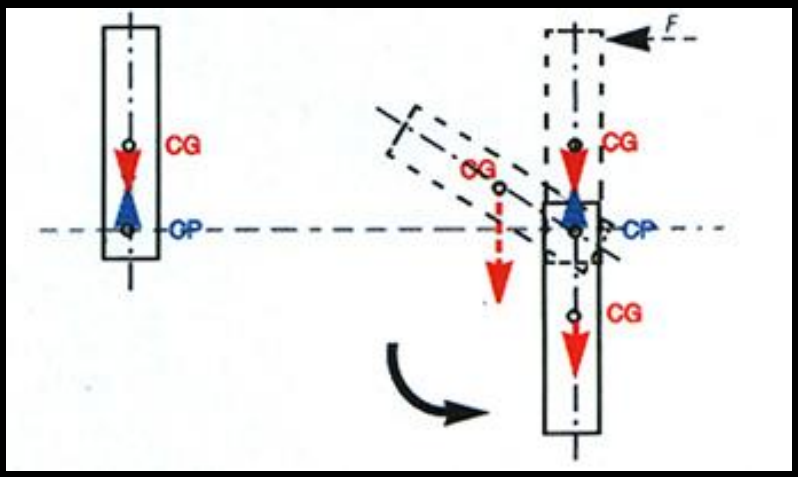


This tendency, or stability, is stronger as the the "hanging point" is higher above the center of gravity. Consequence: When the "hanging point" is higher above the center of gravity, it is more difficult to displace the body from its state of equilibrium, so, then a body is less maneuverable. This is because the center of gravity accompanied with a "hanging point", in that case, present a greater moment of resistance. (A force can be defined as an action that can set a body into translational motion. If the force is eccentric, it will create a "moment", an action that can set a body into rotational motion.)

…and the same is with a free fall. While falling in the most stable body positions, it is very difficult to maneuver quickly and instantly for the same reason. Also, if a skydiver were to lower his “hanging point”, the distance between the “hanging point” and center of gravity will be less and thus, the moment of resistance will be also less. In other words, the skydiver will be less stable but more maneuverable. Maneuvering now is faster and easier.



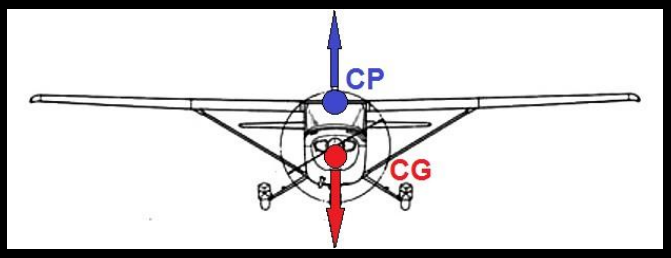
If the “hanging point” is lowered sufficiently such that it is at the same location as the center of gravity, the body will no longer have any tendency to return to its original state of equilibrium. A body will be in equilibrium in any position. This is called indifferential stability. Assuming that there is no friction at the “hanging point”, the body will freely, without resistance (except inertial resistance only), move when some eccentric force is applied. In other words, the maneuverability of the body is yet further increased.

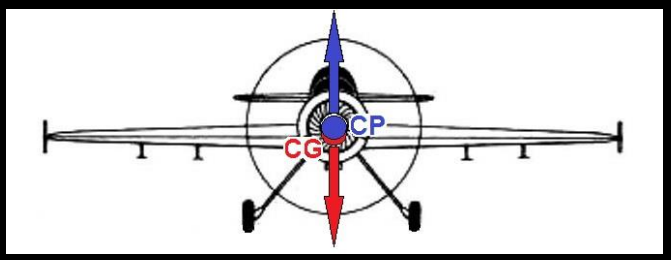


If the “hanging point is lowered even more such that it is actually below the center of gravity, then the body becomes unstable. If displaced by the force, the body will go into a new position of equilibrium. The moment created by the forces exerted on the “hanging point” and center of gravity will cause that transition. The lower the “hanging point”, the greater the tendency to transition. In this unstable position maneuverability is yet even more increased. Just apply the initial force and the center of gravity accompanied with “hanging point” will do the rest...

While moving limbs of the body, we should note that the center of gravity of the body also moves. However, the “hanging point” moves much more and thus this shifting of the center of gravity is negligible. For the purposes of this discussion, we assume that the center of gravity remains at one point and does not move relative to the body.

This relationship of stability and maneuverability also applies to the construction of the airplanes. To make maneuver, a more stable airplane needs to deflect more wind with its control surfaces then a less stable airplane. Or, for the same amount of wind deflection off control surfaces, a less stable airplane is able to make a quicker snappier maneuver. The same concept applies in skydiving. To perform either a translational, rotational or transitional maneuver in a less stable free fall position, less wind deflection is needed then when flying in a more stable position. This allows us to fly more efficiently. If we decrease our stability even more, this phenomenon will be even more pronounced until we reach the point where we can no longer balance in our unstable body position.





Applications in Skydiving

Every maneuver performed in freefall regardless of the discipline is profoundly affected by this relationship between stability and maneuverability. All maneuvering in freefall is performed by changing the shape of the body.

Beginning skydivers use the most stable positions in freefall. With increasing experience, skydivers unconsciously discover and learn to use a less stable body positions in order to increase their maneuverability.

With increasing experience, skydivers will learn to fly in more and more unstable body positions and thus increase their maneuverability more and more. More experienced skydivers have the body control and balance necessary to fly in even more unstable flying stances and thus achieve nearly maximum maneuverability. Learning to fly unstable body positions will come with experience and better freefall awareness. This requires freefall time since we do not get to practice this type of balancing on the ground.

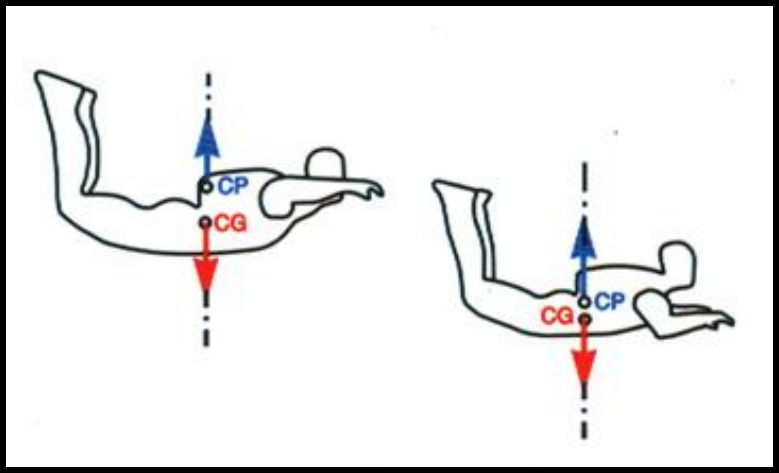
Formation Skydiving

Arizona Airspeed flies over Skydive Arizona, USA.
Photo by: Jason Peters

Advanced relative work skydivers take advantage of using a more unstable box position to achieve quicker maneuverability between formations. Some competitive formation skydivers actually fly with the hands and elbows below the shoulders or chest area. This decreases their stability and therefore quickens their maneuverability.

Because a relative work skydiver presents a large surface area to the relative wind, it is possible to balance on the top of the bubble of air with the “hanging point” below the center of gravity without any unwanted movement. By balancing in this unstable position, the skydiver is able to maneuver more quickly at the instant that he or she desires.

To explore this feeling of increased maneuverability that results from decreased stability, you can try this experiment for yourself.

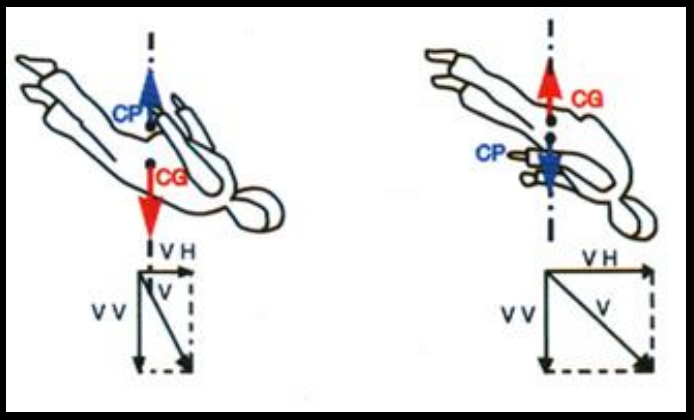


First, perform any maneuver, translation or a turn, with your hands up as you would in the hard arch position. Notice the speed of your translation or turn. Perform the translation or the turn again. But this time, perform it with your elbows and hands position lower, below your shoulders. Notice how quick your translation or turn is. For the same amount of wind deflection, you will notice that your maneuver happens more quickly.

Vladimir Milosavljevic & Wilma Dereta demonstrate less and more stable body position over Texel island, Holland.
Photo by: Max Dereta

As you continue to experiment, you will also notice that if you want to perform a maneuver more slowly in an unstable position, you will have to deflect less wind than you would if flying in a more stable box position. This experiment illustrates how you can make your flying more efficient by using a more unstable box position...

Tracking



By decreasing your stability in tracking position by rolling the shoulders forward, lowering the hands, and raising your seat, you can significantly increase your horizontal speed while maintaining the same or even slower vertical fall rate. This increases your gliding distance.

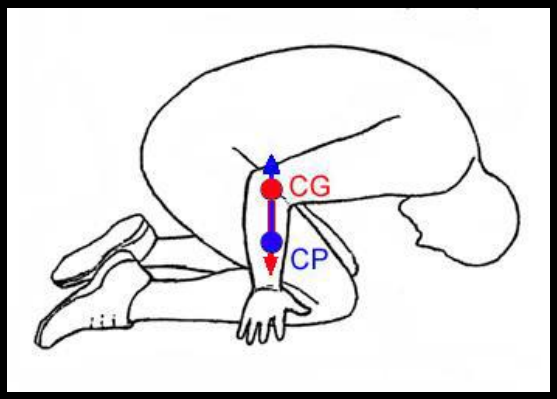
However, making yourself even more unstable by de-arching even more (such that you could easily tumble into your back) will not increase your horizontal speed due to the increased drag opposing the forward motion. However, this will decrease your fall rate and still further extend your gliding distance. In other words, de-arching a little bit will significantly increase the horizontal speed since the horizontal drag is not significant. To achieve the maximum gliding distance, the “hanging point” must be below your center of gravity. (This tracking technique can also be useful for increasing the gliding distance when BASE jumping from high objects.)

Vladimir Milosavljevic demonstrates stable and unstable tracking position over Skydive Dallas, USA.
Photo by Gary Haass

Classic Style

Cheryl Stearns maneuvers over Raeford, NC, USA. Photo by: Sean Capogreco

Style jumpers routinely take advantage of the additional maneuverability made possible by flying in the more unstable style tuck. The hands and legs are actually positioned below the torso. In the style tuck position, the amount of drag below the center of gravity is increased . This positions the “hanging point” below the center of gravity , hence the skill necessary to even remain balanced in this position. A style jumper flies with the “hanging point” (in relation to the center of gravity) as low as he or she is able, without tumbling over into his or her back. While using the unstable style tuck position, a style jumper is able to perform quicker turns and loops. With a more stable body position such fast maneuvering would not be possible.



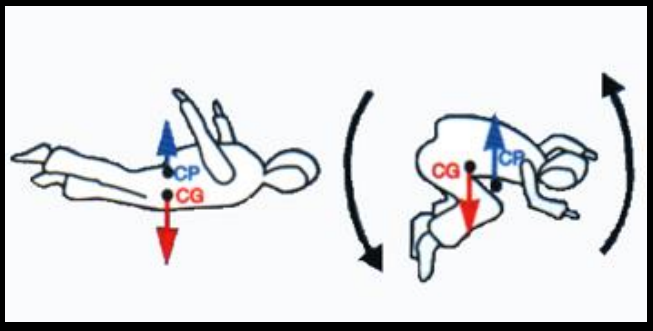
Freestyle

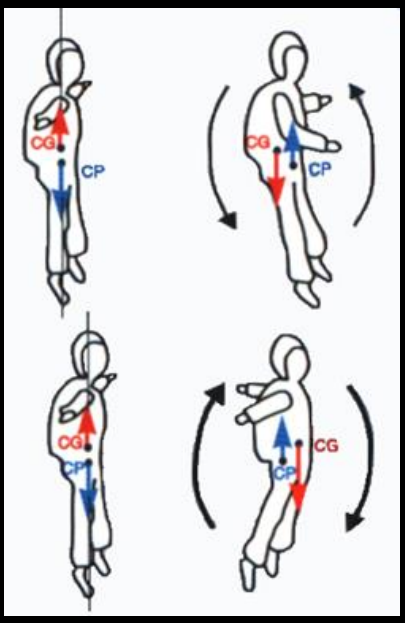
Tamara Koyn flies in "T" position over Missouri River Valley, MO, USA. Photo by: Jamie Paul

In freestyle, a tumble rotation (such as a barrel roll, cartwheel, or loop) can only occur if the “hanging point” is below the center of gravity. (Note that a turn or a pirouette, a rotation causing the heading to change, can be performed even when the “hanging point” is above the center of gravity.) Freestyle skydivers who keep this in mind can better choreograph the transitions between moves in their routines.

A freestylist can not initiate Layout Backloops without tucking or bending the body if they are starting from a position in which the “hanging point” is above the center of gravity. From a face down position, some tucking of the legs and bending in the hips is necessary to lower the “hanging point” and start maneuver.

The lower you put the “hanging point”, the easier it will be to start maneuver. The maneuver itself will be also faster.





For example, from a standing position, with the “hanging point” already below your center of gravity, the freestylist can easily initiate Layout Backloops maintaining straight body position without any extra tucking in the limbs and bending in the hips.

However, from a standing position, the “hanging point” is already below the center of gravity and the freestylist can initiate Layout Backloops maintaining the straight body position without any extra tucking of the limbs and bending in the hips.

A transition that progresses from an unstable position to a stable position will be easier transition to perform. Initiating a barrel rolling, cartwheeling, or looping move requires that the “hanging point” be below the center of gravity. If it is not already there, the freestylist will have to invent an aesthetically pleasing precursor movement that will lower the “hanging point” below the center of gravity before they can proceed.

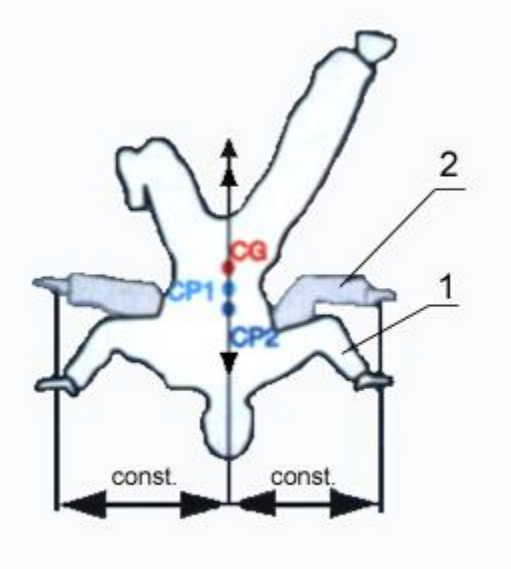
In freestyle competition, Tamara used a freestyle suit with corduroy fabric on the forearms and the lower legs to make it easier to lower the “hanging point” below the center of gravity as desired (as well as other aerodynamic purposes) and to take advantage of more unstable flying for performing various maneuvers.

*****Freeflying*****

Freeflying in a headup or head-down position is more unstable and thus freeflying involves a higher learning curve than a relative work. Maneuvers happen more quickly not only due to the faster fall rates attained in the freeflying but also because the body positions used in freeflying are more unstable.

In “The Art of vRW; The Way of Freefly”, Pat Works talks about stability and freeflyers. By presenting more or less of the upper or lower body to the relative wind while head-up or head-down, a freeflyer can control the position of his or her “hanging point”. The higher the “hanging point” and thus the less unstable the position, the easier it is for the beginning freeflyers to learn the head-up and a head-down flying stances. For example, spreading the legs as wide as possible and allowing the arms to blow back or even tucked into the chest raises the “hanging point” and makes the head-down stance easier to balance.

Tamara Koyn performs more and less stable basic freefly position over Quincy, Ill, USA.
Photo by: Glen "Stuwy" Newman



As freeflyers gain skill, they will take advantage of more and more unstable body positions. For example, French freeflyer Philippe Vallaud reported that he could perform faster head-up pirouettes or turns if he flies with the hands positioned as far downward as possible.

If you are an advanced freeflyer, try this experiment for yourself. While flying head-down, use only your legs to perform head down pirouettes or turns. Try this first with your arms blown back in the swept back position. Repeat the maneuver with your hands held over your head as if you are holding two large dinner platters. Be sure that your arm position is the only thing that you change. Be sure that your hands are still at the same distance from your spine as you try this experiment. Be sure that you use the same identical leg movements for performing your pirouettes or turns. Notice the difference in the speed of your pirouettes or turns.

*****General Conclusions*****

To understand and take advantage of greater maneuverability possible when flying in more unstable positions, there are a few general conclusions that you can keep in mind.

Firstly, you can not maneuver as quickly if you do not use more unstable flying stance.

Secondly, the more you increase the drag below your center of gravity, the lower you move your “hanging point”. This decreases your stability. The more you decrease your stability, the more maneuverable you become. The more you increase the drag above your center of gravity, the more you raise your “hanging point”. This increases your stability and thus decreases your maneuverability.

Thirdly, the degree of stability or instability depends on the distance of the “hanging point” above or below the center of gravity respectively.

Vladimir Milosavljevic demonstrates convex and concave surfaces (body positions) exposed to the relative wind. Skydive Dallas, USA. Photo by: Gary Haass

In the terms of body position, if more convex surfaces are exposed to the relative wind, the body position is more stable. For example, while arching, you are presenting a convex surface to the relative wind. If concave surfaces are exposed to the relative wind, the body position is more unstable. A reverse arch

position is one example of concave surface exposed to the relative wind. This general rule gives you an idea on how your body should look in the freefall in order to have the degree of stability you desire. You can think of your arms and legs as the feathers of an arrow and by using them you can change your stability as desired.

Final Observations

Skydivers, who learn about the theory, will be able to take advantage of it immediately and thus experience a faster learning curve. Theoretical knowledge is always a huge short-cut, enabling you to learn more in less freefall time, less jumps, and thus less money. By having the theoretical knowledge, you can deliberately and consciously make adjustments to your body position in freefall to achieve the aerodynamic results that you desire. Most importantly, you should know your skydiving goals and what you wish to achieve with the body positions in which you fly.

Robb Harris and Patrick de Gayardon fly over Skydive AZ, USA. Photo by: Jamie Paul

Jumpsuit adjustments and features also help you to adjust your stability as desired. Jumpsuits for student skydivers can be designed to keep the drag (and thus the “hanging point”) above the center of gravity as much as possible, in order to help students to be more stable. Students will be able to make more mistakes without going into unwanted maneuvers and thus increase their enjoyment level in the beginning, before they learn to control unstable positions. Examples of this are already around. Sit Flying and Skysurfing suits have wings on the arms. Beginning Skysurfers start with the smaller board before moving up to a larger board. Advanced skydivers may use jumpsuit features and equipment that actually decrease their stability. For example, style jumpers wear a slick jumpsuit with a large gloves on the hands.

The authors sincerely hope that this article will inspire jumpsuit designers to create new design ideas and skydivers to consider new freefalling maneuvering techniques.

The air does not care who is freefalling through it. The air only recognizes the shape of the body exposed to the relative wind. This theory of skydiving stability offers explanations in print for your study. ...and we are sure that once you understand it and use it in your skydiving, your freefall maneuvers will be more efficient and easier to accomplish!

Vladimir Milosavljevic & Tamara Koyn

Wilma Dereta flies in wing suit over Rio de Janeiro, Brazil. Photo by: Max Dereta

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***** This article was published in 1999, 2000 and 2001 in 9 countries on 6 different languages. Magazines and countries that have published the article were: PARA Mag - France, Skydive MAG - UK, Sport Parachutist - Holland, US Parachutist - USA, Spazio Verticale - Italy, Australian Skydiving Magazine - Australia, Canpara - Canada, Fritfall - Norway and AERO magazin - Yugoslavia.**

Upon publishing this article, Vladimir and Tamara produced skydiving instructional video “Body Pilot in Command”. Part of this video you can see at: https://www.youtube.com/watch?v=cy19UQcN0uY