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**THE ART OF VRW**  
THE WAY OF FREEFLY

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This book is dedicated to

Janner

and



Magic John Schuman,  
Wizard & Grand Director of  
Skydance Choreography [Hail!]

## FOREWORD

When I started skydiving in 1974, the still-new, really happening thing to do was learn new ways to have freefall fun with your friends. It was called “relative work,” or RW, and it was wild and crazy compared to the stodgy, old style and accuracy people.

The style people wore tight suits and made hundreds of jumps doing the exact same flat turns and vertical transitions as the last jump – except maybe a hundredth of a second faster, or two degrees more precisely.

“Arrduhb,” on the other hand, was looser, freer, more fun. Every dive was different, there was always a lot to giggle about – and you got to actually jump with the people you liked to hang out with on the ground.

The whole environment surrounding arrduhb was dynamic. Because it was a new discipline, nobody had the corner on knowledge and experience. And the people who did become instructors and leaders were accessible role models; unlike the stodgy people in tight suits who had so many jumps, the arrduhb people were new to the sport and relatively inexperienced. And since the total knowledge/experience base was low, you could get proficient enough to have fun and brag after just a few jumps.

As a result, jumpers off student status flocked to arrduhb in ever greater numbers. Gurus sprouted: Jerry Bird, Skcratch Garrison, Pat Works. Books were written, most notably: *“Body Flight”* by Carl Nelson and *“The Art of Freefall Relative Work”* by Pat Works.

In remarkably short order, the face of sport parachuting changed worldwide. Arrduhb soon became the principal coin of recreation and competition. Four-way became the focal point. Competitive standards have now reached such a level that it is routine for even casual four-way teams to make hundreds of jumps doing the exact same flat turns and vertical transitions as the last jump – except maybe a hundredth of a second faster, or two degrees more precisely.

So guess what? It's almost 2000 and the still-new, really happening thing to do is learn new ways to have freefall fun with your friends. It is not called arrduhb, but it IS wild and crazy compared to the stodgy style of four-way.

And guess what else? Pat Works is out there on the leading edge again. He's older and greyer, but otherwise, things are pretty much the same: He's found old methods to teach new ways to have fun in freefall. His 36 years of skydiving and instructing have produced a sort of hybrid sensei approach that blends training used in martial arts, computer science, and dance with a healthy dose of Works Quantum Weirdness. (Kind of a combination of New Age babble and Black Death bohemianism.)

Like he did 25 years ago with arrduhb, Pat's making lots of jumps and doing lots of seminars and churning out huge volumes of speech and information. "*The Art of vRW: The Way of Freefly*" is the distillation of that effort. And like its predecessors, "*The Art of Freefall Relative Work*" and "*United We Fall*," its purchase price will be repaid many times over in futile and even unsafe jumps avoided – and in extra accomplishment and fun gained.

Robin Heid  
Crawford, Colorado

## Preface

It seems we are at the dawn of a somewhat mysterious new day. Some day freeflying, the newest dimension of skydiving, will be more common. That day is coming. Now, we are in a pre-dawn period—just before sunrise, as darkness and mystery give way to light and understanding. As this is the sunrise of freefly, things such as technique are indistinct and still dark, and understanding has yet to see the light of day.

It has happened this way before. Today reminds me a lot of the 1960s, when the basic concepts of relative work were still emerging. Back then, such fundamental notions as the basic RW positions were neither understood nor agreed on. Consider, for example, that there was once controversy over whether the *basic stable* or the *French frog* (boxman) was superior for doing baton passes or contact freefall parachuting. Words such as *relative work*, *star*, and *grip* did not find their way into my logbook until the mid-1960s. Today, more than 30 years later, it is the "high noon" of RW skydiving.

In this new vertical dimension of RW skydiving, except for a few articles that have appeared in *Parachutist* and *Skydiving* magazines on the topic, the "how-to" concepts are still not clear. And so, this is a book of techniques for the skydiver who would perfect freefall flying in the vertical.

It is a book about attitude as well; of control ... and abandon. It is meant to be read and studied as you progress toward perfect freedom of expression in flight. It was written with the understanding that skydivers will forever test their wings to achieve the dreams of flight we all share.

Pat Works  
Fullerton, California

July 1998

# INTRODUCTION

## Flight for the Joy of Flying

The information that follows presents a proven approach to learning the art of flying the body in a vertical sky, and to better understand the way of perfect freeflight. Study, search, and meditation reveal the secrets of freefall body-flying, whether horizontal relative work (RW) or vertical (vRW). So watch, learn, discover, and fly—but don't forget to study and contemplate, too! Where complex contortions and stilted over-exertion sometimes fail, simple practice and spirit training almost always lead to perfect flight.

The vRW movements of freeflying allow skydivers to express their artistry in freefall, and to fly to entertain each other and themselves. Whatever the motive, a good vRW skydive, like all skydives, is a rite—a ceremony joyfully relating airplane, sky, people, and earth.

**Goal and Vision.** Our freeflying goal is flight for the joy of flying. Our vision is to reflect the beauty of freefly with aerial dances. Goal-directed and vision-clear, we can now proceed to get down and enter the way of freefly together!

**Skydance.** Freeflying becomes skydance when the flyers choreograph the levels, presentation, and proximity to present aesthetically pleasing visuals. In skydancing, vRW offers some new ways to satisfy your desire to express yourself. This book and its accompanying video are a compass in the world of freeflight—a way to get your bearings, if you will.

**A Moving Meditation.** Freely is the exhilarating physical action of the flight; it is also an inner philosophical direction. If the inner direction from the mind is faulty and has as its goal completion of formation or speed, the resulting flight will be inferior. As the Elder advised Jonathan Livingston Seagull in Richard Bach's must-read book of the same name:<sup>1</sup>

“Heaven is being perfect... you will begin to touch heaven, Jonathan, in the moment that you touch perfect speed. And that isn't flying a thousand miles an hour, or a million, or flying at the speed of light. Because any number is a limit, and perfection doesn't have limits. Perfect speed, my son, is being there.”

**Relaxed Aggression.** Being good ... being fast ... being *there* ... comes from subconsciously looking ahead a few tenths of a second earlier than you usually do. Looking ahead leads to greater relaxation, smoother movements, quicker thinking, faster reactions, and greater appreciation of the beauty of freeflying. Your jerky movements will soon become smooth.

In vertical flight, the successful flyer acts on the exact moment of each movement and in real-time joy. Perfect flight is like breathing. In perfect vertical flight, later never exists and the past is gone away forever so that every part of you is centered on the now. Enlightened, you realize that the time-triad of past-time, present-time, and future-time is but a single time: Now.

**Goal Attainment.** Freely demands thinking about the way of getting there so that you propel yourself down the road to perfect body flight. Mileposts along the way tell us where we are, and in freeflying, fun is a milepost on the way to the next one—more fun and greater fulfillment in freefall.

**Freely and Art.** Artful freely is the essence of unrestricted flight. Its practice instills an appreciation of deeper arts, and

rewards its devotees (you sky-dudes and dude-ettes) with perfection, harmony, and beauty.

And so, this package—a book and accompanying video—is a mixed-media storehouse of techniques skydivers can use to perfect their art of vRW. If you have a sense of humor, can laugh at yourself, and love to fly, begin freeflying today—so we can skydance together tomorrow.



## Out!

Blinding sky-blue snatch  
a silent Otter.

Puffy clouds softly gather;  
sail on wonder.

Wind drum beats echo  
whoops and giggles.

Laughing flyers' mind's-eyes  
hear it all.

## Imperious!

Dance vertical wind song  
on uprushed air.

Present tender selves  
to a hot-eye sun.

Clouds, too, soar on wings  
self-won.

<sup>1</sup> Bach, R., *Jonathan Livingston Seagull*, Macmillan, 1970.

# Group Swoop Definitions

**Relative Work (RW)** — From the French “*relatif*”; a.k.a. conventional skydiving or flat flying – An art practiced by skydivers since the 1950s, RW entails the intentional maneuvering of two or more freefall skydivers in relationship to each other. Levels and proximity are key to the meaning of “relative work.” The aim is to adjust levels and proximity to build formations and to fly slots. In traditional RW formation skydives, participants fly to complete the group’s goal formation(s). In sequential formation RW competition, the goal is to make points—one point awarded for each completed formation. The team that can make the most points in the least amount of time wins; aesthetics are irrelevant. The flight paths are planar, and generally 2-D, i.e. “flat-land.” The rules of competition are mature and well defined. RW formations are presented to a camera usually from above or below.

**Sit-flying** — a.k.a. Chute Assis or Freak Brother Flying (1970s) – A skydiving discipline that focuses on the ability to control levels and proximity while flying butt-to-earth positions. Sit-flying relative work is three-dimensional. As in competitive RW, the goal of competitive sit-flying RW (1994-95) was to make points. However, unlike Relative Work, sit-flying skydivers may attempt to express physical artistry with freefall body movement, although aesthetic body form is a great deal less important than is good level and proximity control between team members. Video presentation is usually from the side. Draft rules for sit-flying competition have been published and were tested at Tony Uragallo’s 1994 First Exhibition Event of Sit-Flying. Often

merged with freeflying, sit-flying is considered a required freefly skill.

**Freeflying or Vertical RW (vRW)** — An emerging skydiving discipline (first practiced by Olav Zipser, 1986) that focuses on the ability to control levels and proximity while flying vertical positions (initially with the head into the wind.) Today, vertical RW embraces a variety of body positions to fly relative with others at *any* fall-rate. Freeflyers do their vertical relative work in a variety of modes including head-down, standing, sitting, back-flying, and belly-flying. Pretty, graceful body form is not the most important aspect in vertical RW; rather, as in all forms of RW, precise control of levels and proximity is the main objective. The intent is to be able to fly in any position relative to another skydiver within a space constrained only by time. Compared to “flat” or planar RW, vRW is spherical or three-dimensional. Larger formations resemble a swarm of bees more than a dinner plate. To illustrate, RW dives can be stamped out on a flat piece of paper, while vRW dives cannot. Video presentation is from the side or a 3-D spherical point-of-view.

**SSI Pro Tour Freeflying** — Freeflying Pairs, McKee-man, 1995 – Freefly competitions organized by SSI and held throughout the USA and Europe, the competitions are titled the *SSI Pro Tour*. The SSI Pro Tour is not a traditional parachuting competition. It is part competition, part TV show, part parachute demonstration, and part special event. *SSI Pro Tour Freeflying* is a team parachuting discipline consisting of three athletes, two freeflyers and a camera flyer, who fly mostly vertical body positions. The camera flyer records the performance of the freeflyers and contributes to the per-

formance interactively through his or her creative and athletic skills. Aesthetics matter. SSI competitions use the “subjective camera” approach. This format applies a participatory or subjective role to how the camera is used, as opposed to a passive or objective role. This concept means that what is scored is not just the tricks shown, but also how the tricks are presented.


**Skydance** — From *Skratch*, 1960s; *Magic John*, 1990s — A form of progressive skydiving that includes RW, chute assis, and vRW. Freeflying becomes a dance in the sky when the flyers choreograph the levels, presentation, and proximity to present aesthetically pleasing visuals. More simply, any multi-person freefly skydive having both rhythm and choreography is a skydance. In a skydance, flying movements are an end in themselves. Skydance is a frame of mind where skydivers dance in the sky to entertain other skydivers. Beautiful and graceful body form is as important as level and proximity control. Vertical, spherical, and 3-D air moves are involved; beauty in motion is linked to rhythm so that the concepts of group aerial dance, video, and music merge. The only rule of progressive skydiving is that there are no rules. Video presentation is whatever works (i.e., any dancer can wear a camera.)

*References: Skratch Garrison, Tamara Koyn, Pete McKeeman, John Schuman, Tony Uragallo, Pat Works*

## Chapter 1

# OUT OF THE BOX

## A Freefly Frame of Mind

 It was the potential for unbounded spherical freefall flight that lured me out of the box and into the vertical world of freefly. I have always wanted to experience unlimited flight. I have long yearned for true skydance, and vRW is both. That much I expected. What I did not expect is the beauty. Exit, and “*pow!*” the enhanced color is delicious!

Perhaps it’s the air—2.5 miles up, the air is clear and bright, the scenery sensational. Where I jump, snow-peaked mountains face off the bright Pacific on two sides of my dance floor—the intensely deep blue sky. This sky becomes my playground, where beauty, challenge, freedom, and joy await me. “Viva la revolución freefly! Viva!”

In vRW, the sky unfolds into a 360-degree dome around you. The less interesting ground is barely in your field of vision. Still—out of sight and out of mind—it thunders upward. Even for experienced freeflyers it’s an effort to both observe the approaching ground *and* to freefly, particularly while performing vRW’s lightning fast moves at the faster freefall speeds of freefly.

Freefly, like all of skydiving, has risks. Some of them are unique to vRW—high-speed instability will sling you across the sky in a heartbeat, for example, and when you screw up, you can pop into a skymate. The “going low” of horizontal RW becomes the collision risk of “falling up” in vRW. It’s called *corking* and is one of the perils every beginning freeflyer should know about.



When you fall out of a freefly move, you can shoot upward *and* across the sky at 70 mph. Even people 100 feet away from you can be hit by a flying cork—you.

It is easier to relax and have fun when you are not bleeding. So, *knowing* what the dangers are and *practicing* good danger avoidance affords the best skydives. More importantly, we are duty bound to communicate the basic safety tenets of freefly. In our quest for perfect flight on the way of freefly, we will discover the what, the why, and the how, converging again with danger avoidance in Chapter 8, *Reality Bites*, where the essential realities of altitude awareness, gear safety, and large group freefly danger are covered in more detail.

But first, we set the stage by agreeing to agree on common definitions for fall-rates and swoop modes. Then we present the physics of freefly. From the exit, through the turnin' and burnin' of vRW, the opening and the landings, knowing the mathematical and physical underpinnings is valuable for the pictures of flight they paint on our mind's eyes. The purpose of this discussion is to promote better understanding of solutions to practical problems in freefly, in the expectation they will lead us to greater skills and safer flying by more knowledgeable freeflyers.

To better appreciate the potential for trouble that beginning freeflyers will encounter, try the following experiment:

On a sultry day, driving along with no particular place to go, a pleasant pastime is to hang your arm out of the car window and "fly" it on the passing air. Driving along at, say 60 mph, you can both feel the wind and fly your hand on its back. Cupping your hand, spreading the fingers, presenting the palm flat to the wind, changing the angle of attack—you can dive and soar at will. This is something that most everyone has experienced.

It is instructive to take that car up to, say 85 mph, while flying your hand. But this time, fly the hand edge-on. Hold it like a karate-chop, edge into the wind. Instead of the flat of your hand doing the flying, it's the edge. Now, change the angle of attack. Whoops! Edge on, at higher speeds, you get a much faster reaction

—so much so that you can painfully bang your arm into the window frame.

Compared to the flat-palm effect, it takes a smaller deflection to get considerable reaction. The same thing is true of vRW where the vertical, edge-on act of presenting your body to relative wind speeds of around 200 mph produces a magnified reaction that can send you unintentionally zooming all over the place or popping up like a cork released under water. (Yes, that's why freeflyers call it *corking*.)

Horizontal RW flyers who are accustomed to having to use a limited number of body positions and pushing hard to get modest movement can find this hair-trigger response unsettling. To the skilled vertical modes freeflyer, it means greater maneuverability using less energy. Freeflyers accept the risk that higher speeds and instant changes in speed increase the possibility of collision. Their repertoire of useful body positions extends from flat-only to include four others.

## Swoop Modes

Apart from "standard" (traditional) belly flying, there are four other types of freefly skydiving: sit-fly, standing, back-fly, and head-down. In each of these modes it is possible to do turns, loops, rolls, spins, and other movements that can be either wind-borne (aerodynamically flown) or gymnastic (using kinetic energy.)

**Mode A: Horizontal RW, prone, chest and face-to-earth.** "Belly-flying" or flat flying. The spine is parallel with the horizon. The relative wind is on the chest; the back and butt face the sky. Variants include the RW stable and boxman; and freestyle's stags and "T."

**Mode B: Sitting, butt-to-earth.** Also known as "chute assis" or "Freak Brother" flying. On-the-butt orientation where the buttocks are always facing the ground. The relative wind is on the seat of the pants and soles of the feet. The spine and back of the head are perpendicular to the horizon line.

**Mode C: Supine, or lying back-to-earth.** Also known as back-flying. On-the-back orientation where the chest faces upward, toward the sky. The relative wind is on the back and calves of the legs. The spine and back of the head are parallel to the horizon line. Variations include freestyle's teardrops, "magic ball," and inverted track (back-track.)

**Mode D: Standing, feet-to-earth.** "Upright" orientation with the head uppermost. The spine and the head are perpendicular to the horizon line. The relative wind is on the soles of the feet. Variations include the daffy, straddle, split, hang-ten, standing track, no-arms, etc.

**Mode E: Inverted, head-to-earth.** "Downright" orientation with the feet uppermost. The relative wind is on the head and shoulders. Variations include the blind-dive, headstand, Olav, Romeo (forward/aft,) foot-to-the sun, etc.

You can add "music" to your skydiving by flying combinations of these modes. Do it with groups of your friends—don't forget to invite one or more cameras!

## Measuring Relative Fall-Rates

Now, we discuss measurement of fall-rates: from abstract concepts to concrete representations. Cloud Dancer (Tamara Koyn) gave us *scales* or levels of measurement for discussing skydiving. Her operational definitions specified how she scales a *variable* (body position speed) to assign a relative velocity score to a skydive body position. Here then are operational definitions mapped to her relative speeds.

## Ordinal Scales

To minimize in-air groping, assume that skydiver body position fall-rates have numerical scales like the familiar IQ intelligence score, on which higher numbers indicate more of the construct. That is to say, Ms. Koyn's fall-rate numbers are *Ordinal Scales of Measure*.

An ordinal scale contains categories that can be ordered by rank on a continuum. The categories have a rudimentary

arithmetic meaning more or less of the quantity being measured (velocity in feet per second.) This freefall measurement scale states that **1** means a position that permits less speed than **3**, and that **2** is located in-between. The interval between **1** and **2** may be larger or smaller than the interval between **2** and **3**. If that sounds confusing, think of it this way: An ordinal scale does not imply anything about the arithmetic values other than that they are in order.

In any event, in each category of fall-rate, freeflyers learn to control levels and proximity. According to Olav Zipser, Tamara Koyn, and others, fall-rate can be divided into five basic categories:

1. **SLOW – Speed 1** – the basic boxman "RW stable" position.
2. **MEDIUM – Speed 2** – the fall-rate ranges attainable from the seated position.
3. **FAST – Speed 3** – fall-rate ranges attainable in the standing and Olav side-by-side (head-down with limbs spread) positions.
4. **STREAMLINED – Speed 4** – fall-rate ranges attainable in streamlined positions.



Figure 1. Whatever your fall-rate and favorite swoop modes are, let's be careful up there.

5. **HIGH SPEED – Speed 5** – a tandem in a head-down at terminal, etc.

To better understand fall-rates, it is helpful to consider them in terms of standard freefall positions or *swoop modes*. Said another way, it is instructive to integrate concepts of fall-rates with swoop modes.

Fall-Rates and Swoop Modes:

Swoop Modes	Fall-Rates
Mode A: Horizontal (traditional) RW, prone, chest and face-to-earth	SLOW – Speed 1. Fall-rate ranges attainable in the prone, such as the basic box position commonly used by sequential relative workers. Swoop Mode A seems to compare with speeds 0.9 up to 1.5. The fall-rate factor for the “T” position is approximately 1.3.
Mode B: Sitting, butt-to-earth and Mode C: Supine, or lying back-to-earth	MEDIUM – Speed 2. Swoop Modes B & C seem to compare with speeds 1.6 up to 2.5. Fall-rate ranges attainable from the seated position with torso near vertical, or a supine position with the legs partially tucked. Mode C in a “magic ball” can fall up to 3.5.
Mode C: Supine, or lying back-to-earth and Mode D: Standing, feet-to-earth	MEDIUM-FAST – Speeds 2 & 3. Swoop Mode C seems to compare with Speeds 2.0 up to 3.0. The fall-rate factor for a Daffy is approximately 2.0. (It would be slightly faster if the freestylist has less flexibility, i.e. less surface area exposed to the wind flow.) The fall-rate factor for Back Layouts is approximately 2.8.

Swoop Modes	Fall-Rates
Mode E: Inverted, head-to-earth	MEDIUM-STREAMLINED – Speeds 3 & 4.  Swoop Mode E seems to compare with Speeds 3.0 up to 4.0. The average camera flyer begins to experience difficulty when attempting to film freestylers falling faster than fall-rate factor 3.0. Mode E is Fast (Speeds 3-4) with fall-rate ranges attainable in the Standing (with legs somewhat spread) and the Olav side-by-side (head-down with the limbs spread and catching air) positions. The fall-rate factor for a Stand-up (with arms 90° out to the sides) is around 3.7.  Mode E is also Streamlined (Speed 4) with fall-rate ranges attainable while holding streamlined positions such as a no-lift dive, blind dive, or stand-up (with legs together and arms out of the airflow) catching as little air as possible.
Mega-Mondo Mode: ultra-fast	HIGH SPEED – Speed 5. Fall-rate ranges for this Swoop Mode – undefined for its many variations – are extreme high speed. Consider Totem formations, toe-docked stand-ups, a head-down tandem at terminal, a bag of bricks, a watermelon, and a sack of sand.

Fall-rate measurements allow us to discuss skydiving modes with a common language. These numbers provide us with a useful guide for designing and performing mixed-mode skydiving on the same jump. If we want to skydance together (and videotape it) we must be able to fall together with precise control over both levels and proximity.

Now that we've introduced some of the concepts and shown you some of the possibilities, let's get down to basics.

## The Physics of Freely

Freely is counter-intuitive. This often makes standing vRW difficult and head-down vRW baffling to veteran skydivers. It's not surprising that understanding freely seems like a black art. Coached learning is a problem because there are few teachers. As a result, most freeflyers are either self-taught or try to learn from friends who are unschooled in the basics for training.

Freely schools are not widely available. What coaches there are rely on an oral-only teaching technique, supported by video. To add confusion, there are two paths to learning freely techniques. The first is a mechanical approach; the second is meditative or "natural." Whichever way is taken, understanding of the other way helps because each path offers benefits.

Physics, aerodynamic theory, and charts can support the mechanical process, while the natural approach is reflexive and unconstrained: "Ya jus' gotta *feel* it, dude! Y'know?" or "C'mon up with me and I'll show ya the moves." Just as obscure, the mechanical approach is introduced as a "mathematical and physical study of freefall in the troposphere." . . . Whazzat?

Each approach is a path toward understanding freely. Many remarkable freeflyers espouse the meditative approach. Others prefer the more mechanical approach. Certainly, both attempt to explain vRW's perplexities. However, while the mechanical approach answers the initial questions, it will fall short on the way to ever-better freely. The meditative approach doesn't just answer the questions of freely, it *swallows* questions whole. In one gulp, this way to freely teaches by blending with the learner. It's an art—and key to your flight. If you flail, simply find your center and you will swoop. All easy to say; hard to do.

Understanding the physics of freely helps by getting one intellectually prepared. Understanding ideas like coefficient of drag and center of mass help answer the *why* of vRW. Such terms also make communication about vRW more direct and reliable.

## Freeflight and You

Ever faster speeds on wheels, boats, and airplanes come from careful design studies to maximize performance while minimizing the amount of energy required to attain it. On an automobile, for example, streamlining a side-mounted rearview mirror can be worth an extra five miles an hour in speed. The extra speed comes from the car having less wind resistance. Having less drag improves the efficiency.

We use the term "coefficient of drag" to describe the efficiency of a vehicle traveling through water or air. The smaller the coefficient of drag is, the easier it is for the body to go through a resistant medium. Drag is higher when

- (a) the surface area of the object exposed to the flow is higher,
- and
- (b) the object is moving faster.

Holding your hand outside of a rapidly moving automobile will demonstrate drag for you. To better understand the optimal shape for a body to perform specific tasks, studies have been done on birds, whales, otters, and fish as they fly, glide, dive, hover, and frolic in their respective mediums. This literature on critter drag coefficients is interesting because, like skydivers, they can vary their coefficients by changing their body positions. In fact, all of God's flyers and swimmers change their coefficient of drag numbers through body position.<sup>1</sup>

Skydivers falling face-to-earth with the relative wind on their stomachs have a vertical speed of 110 mph. Freeflyers have a broader range of vertical speeds, ranging from about 130 mph to nearly 200 mph (or faster in special cases.) For two or more freeflyers to be able to stay next to each other while their bodies go through the air at vertical speeds of about 150 mph, they must control very precisely their fall and proximity. They do this by assuming the various body positions that alter both vertical and horizontal speed.

<sup>1</sup> Reference: Philip Yzarn De Loreilhe de Lestaubiere, "*Mathematical and physical study and computer modeling of freefall in the troposphere*," A thesis presented to the faculty of the Graduate School University of Southern California, June 1988.

When a freeflyer goes from a straight head-down to a head-down with hips forward and legs back, or an approach track, he trades vertical for horizontal velocity. The upshot of all this is that by controlling body shape, a skydiver can control both his coefficient of drag and the angle his body makes with the airflow, which is called the relative wind.

Moreover, by presenting more (or less) of the upper body or the lower body to the relative wind, a skydiver can control his or her *center of drag* as well. So, skydivers can increase and decrease drag depending how they configure their bodies. For example, spreading both arms and legs will increase drag rather equally and you will tend to fall flat and stable. Spreading just your arms will increase drag on your upper body. Since center of mass is around your belly button, you will tend to fall feet first. Extending your arms into the relative wind produces more pressure on the upper body. On the other end, extending your legs more into the relative wind produces more air pressure on the lower body.

Upper or lower, the point at which the resultant pressure-force acts is defined as the center of pressure, or center of drag. Center of drag is highly configurable because the body itself is configurable. On the other hand, center of gravity or center of mass is not very changeable. Your center of mass is always around your navel.

Moving your center of drag up your torso, relative to your center of mass, produces a head-up attitude. Thus, for a stand-up or for chute assis, you want a center of drag around your head. You do this by putting your arms out for more drag while decreasing the drag on your legs. Having the center of drag above the center of mass aligns freeflyers, darts, and shuttlecocks to fall point first. In other words, the center of drag of a badminton birdie or a dart is invariably on its feathers (*see Figure 2.*) The center of drag of a head-down freeflyer is always around the feet. Likewise, the head and arms are the center of drag for head-up flight.

Stability is an object's tendency to maintain its attitude or to resist tipping over. Darts and badminton birdies are more stable than freeflying people are. The center of mass being close to a dart

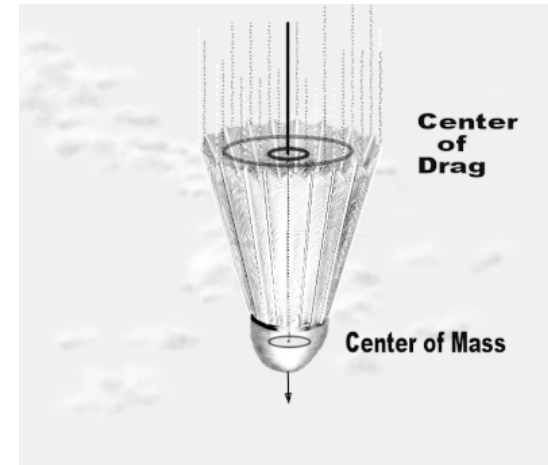


Figure 2. Common objects illustrate centers of mass and drag.

or birdie's pointed end is what gives them stability. The center of mass being close to a freeflyer's middle gives them stability, too, but not much.

That's because an object's stability is determined by the distance between the center of aerodynamic drag and the effective center of mass. Knowing this allows you to be either head-up or head-down by swapping your center of drag from one end to the other (*Figure 3.*) An awareness of where your center of drag is relative to your center of mass is key to becoming an excellent freeflyer.

Like skydivers, gliders, and flying frogs, freeflyers do not just passively descend through the air. Each also has energies that can be redirected for movement. Freefly is all about the amount of energy put into the system to modulate rate of fall and horizontal movement. When freeflyers use their energy to successfully control their levels and proximity relative to others, they can do good vertical relative work.

The relative wind is the wind blast skydivers feel as they go through the air. In this moving reference system, a freeflyer with a speed of 150 mph has a wind that is the same speed hitting him. At this speed, one "feels" the wind as being substantial. Indeed,



*Figure 3. Freeflyers don't need hands and arms to fly either head-up or head-down if they know where their center of drag is.*

one can fly on this wind. By altering their body shape, freeflyers can change position; the immediate result is a change in horizontal movement, a change in vertical speed, or both.

Of course, the relative wind can't be seen. To determine their progress, or lack thereof, skydivers must use external points of reference, such as other skydivers.

Now that you know more about the "why" of freefly stability and movement, read on to initiate your journey of vRW discovery, keeping in mind at all times that:

- 1) The ground lurks.
- 2) There are bold skydivers, there are old skydivers, but there are no old, bold skydivers.
- 3) The trick to making better skydives in the future is to survive those in the present.