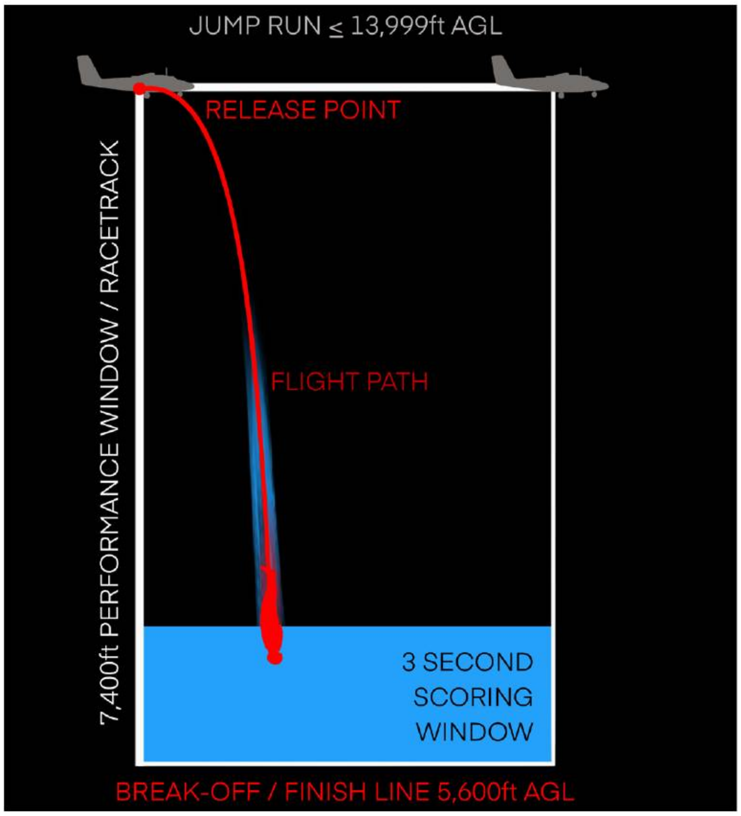
SPEEDING TOWARD THE FUTURE

Text and illustrations by Niklas Daniel

Speed skydiving is the fastest non-motorized sport on Earth. As it increases in popularity and expands from a handful of European practitioners to a growing group of athletes from around the world, skydivers are becoming curious about the discipline. So, where is it now and what is possible—theoretically and practically—as the discipline grows?

For a small few, the dream is to put 600 kmh (373 mph) on a competition score board before the end of the decade. Theoretically, and with some luck, this may be possible, but it is a daunting challenge.



The Precision of Competition

The first thing to understand about speed skydiving—and especially about record-setting—is that it is a competition discipline subject to a specific set of rules. In short, competitors exit below 14,000 feet AGL and enter a "performance window" after they reach a speed of 10 meters per second. The average of a competitor's three fastest consecutive seconds in that window is the score of a run. Competitors wear position logging devices (FlySight GPS recorders) to log their speeds, and these devices are much more accurate at recording speed than are barometric-pressure-based altimeters since the pressure near a jumper's body can fluctuate wildly. Currently, 17 jumpers have broken into the "500 Club" (500 kmh/311 mph) in speed competition history. (So far, all of them have been men, but many women are getting very close.)

The competitor with the highest total at the end of an event (8 rounds) wins the competition, not who has the fastest single scoring round. Therefore, consistency is vital for success. Speed skydives have several phases—exit presentation, flying the hill, the straightaway, and breakoff to slow down to a manageable deployment speed—each with its unique challenges. Because speeders are limited on altitude, they must accelerate as quickly as possible by streamlining. But the more one streamlines, the more difficult it is to maintain control. The slightest wobble has detrimental effects on performance because even a momentary mis-presentation to the relative wind slows them down.

Peak performance rests on three independent variables:

1 | Execution: Skill and Repeatability
2 | Geometry: Combination of flight-orientation, body-posture and equipment
3 | Atmospheric Conditions: Location and Weather

Consequently, competition records are *far* different from performance records. Take, for example, Felix Baumgartner's world record for maximum vertical speed of 1,357.6 kph/843.6 mph, which he set while falling through the thin atmosphere from more than 120,000 feet. With no performance windows or altitude restrictions in place, it's no surprise that the speed was higher, and indeed, he couldn't have gone slower if he wanted to. The accuracy of competition equipment also explains why fun jumpers may momentarily *seem* to log rate of speed that rivals a pro speed skydiver's average of the three-second window over eight rounds.

Falling Down the Rabbit Hole

Speed skydiving aerodynamics is a difficult topic because each competitor has a unique shape. While computational fluid dynamics simulations offer interesting insights when learning to go faster, they need to be accompanied by real-world testing. A jumper must slowly build skill and make aerodynamic refinements over many jumps to gather empirical data on the validity of an idea or technique.

Those looking to reach 600 kmh in competition first need to understand what's possible. Traveling the full length of the performance window in a vacuum without air resistance, a speeder could reach 756 kmh (469.7mph) at 21.45 seconds, meaning it's physically impossible for a speed skydiver to travel faster than 750 kmh in competition. A speeder could reach 600 kmh (372.8 mph) at 17 seconds after falling for 4,650 feet.

Calculating an individual's theoretical peak performance in a competition setting is vastly more difficult when considering air resistance. Competitors are not allowed to wear added weight or use devices that produce thrust. There are no rules dictating which body-flight orientation an athlete must adopt, but a steep, head-down dive is the standard.

In simple terms, if you want to fall as fast as possible, you should have mass (high muscle density) with minimal surface area to minimize drag. While weight is a significant variable, bulking up with muscles appears to have limitations. As mass increases typically so does surface area.

DOING THE MATH

Maximum Velocity in a Vacuum

How fast a speeder could theoretically fall (in kilometers per hour) if the performance window were a vacuum without air resistance.

- Convert 7,400 feet to meters: 7,400 ft * (1 m / 3.28 ft) ≈ 2,256 meters
- Calculate the Time of Fall (h = fall height; g = gravitational acceleration):
  Time t = sqrt ((2 * h) / g) = sqrt ((2 * 2,256 m) / 9.81 m/s^2) ≈ 21.45 seconds
- Calculate the final velocity (g = gravitational acceleration):
  Final Velocity vm = g * t = 9.81 m/s^2 * 21.45 seconds ≈ 210 m/s = 0.210 km/s
  Final Velocity vft = vm * (3.28 ft/m) ≈ 210m/s * (3.28 ft/m) ≈ 689 ft/s
- Convert final velocities to kmh and mph:
  vkmh 0.210km/s * 3600 s/h ≈ 756km/h
  vmph: 756kmh * 0.621371 mi/km ≈ 468 mph

Equation for Terminal Velocity

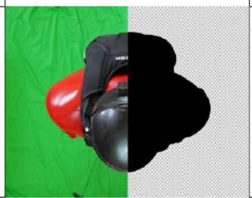
$$v_t = \sqrt{\frac{2mg}{\rho A C_d}}$$

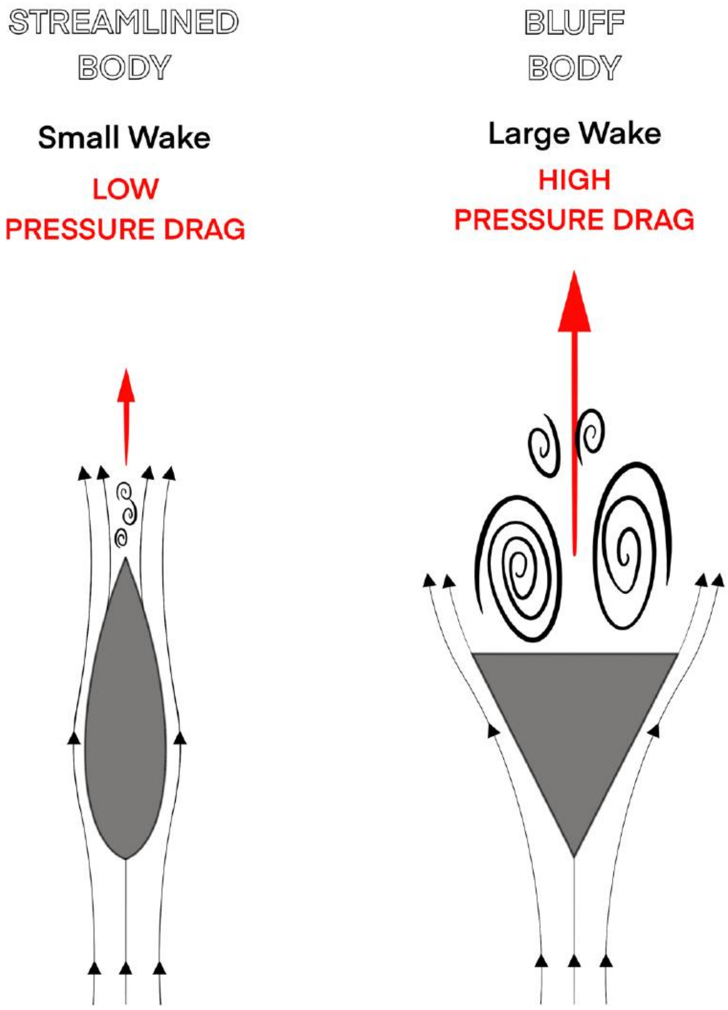
- V_t = terminal velocity, the result when all variables are calculated
- *m* = the mass of the athlete (exit weight)
- *g* = the acceleration due to earth's gravity (9.8 m/s2)
- C_d = the drag coefficient
- *p* = the density of the air through which the athlete is flying (1.23 kg/m3 for air at sea level, and ~0.99 kg/m3 at the middle of the scoring window (2,200m)
- *A* = the projected area of the athlete

Projected Area

Since every competitor is built differently, their optimized method of reducing the projected area—the two-dimensional area the air strikes when viewed on the plane perpendicular to the direction of airflow—will also be unique. As helmets come in only a handful of sizes, the projected area among competitors is fairly similar with success coming from how well they can "hide" their body and rig from the relative wind behind their helmet.

A jumper can alter their fall rate by spreading out or concentrating their mass. By analyzing photographs containing "casted shadows" of different flight-orientations, body postures and alignments, skydivers can determine which posture creates the smallest projected area by counting the number of pixels inside the shadow. The speed skydiver's goal is to find the optimal combination of factors that creates the smallest casted shadow that they can fly without wobbling.

Description	Image (photos by Jochen Althoff)	A - Projected Area (m^2)
High Angle of Attack		0.204
Lower AoA w/wide posture		0.2026
Neutral Spine		0.1647
Arms Forward		0.1639
Personalized method		0.1508

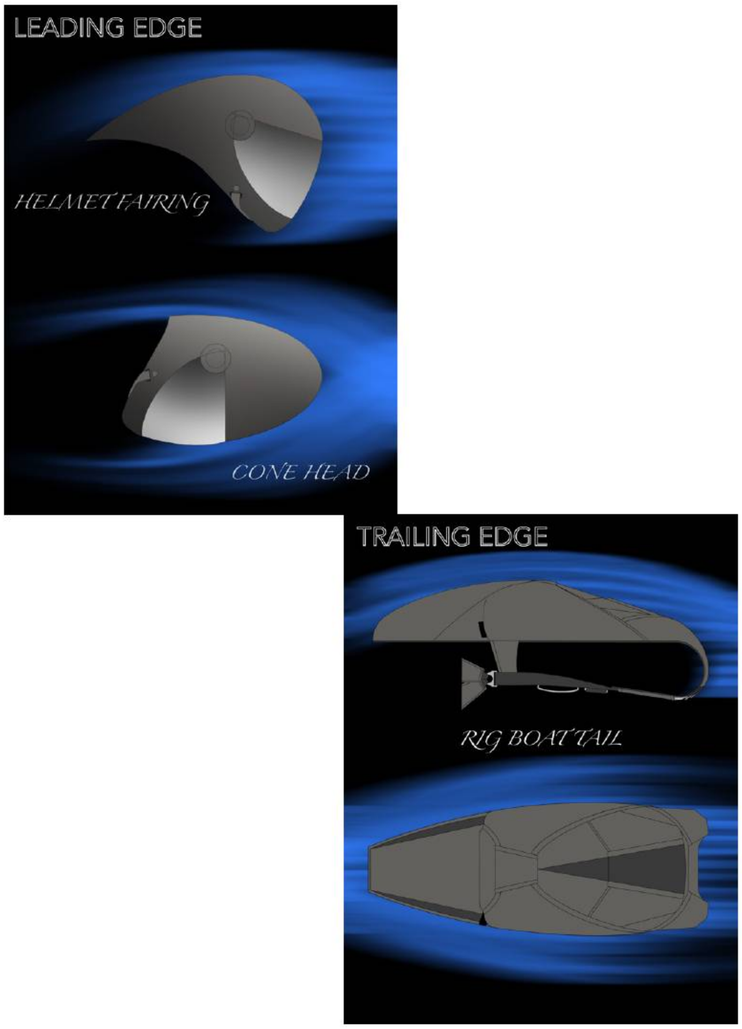


The difference in flows between a streamlined (left) and a bluff body (right): Early flow separation and a large wake containing low pressures produce higher amounts of drag.

Drag Coefficient

Once a speed skydiver tunes in their body-flight skills and technique, the next most important task is minimizing their drag coefficient (Cd). In fluid dynamics, Cd is used to quantify the level of resistance an object experiences in the air, which is associated with a particular shape. The Cd of a jumper includes the effects of parasitic drag, a collective term for all drag components that are not related to lift generation (e.g., form drag, skin friction and interference drag). For example, a belly flyer has an approximate Cd of 1.0 whereas a head-down flyer's is around 0.7. This is why freeflyers typically fall faster than belly flyers. Skilled speed skydivers take it one step further by streamlining their "flying form," which includes equipment, to 0.5 or less.

Reducing the projected area and elongating and tapering the body's trailing surfaces and rig achieves streamlining. Doing so reduces the size of the wake (aka burble) and the resulting pressure drag. However, these changes come at a cost. Increasing an athlete's profile shape (side view) increases skin friction, another type of drag. This is where wearing tight and slick materials can help.



Adding a helmet fairing (top) or a rig boat-tail (bottom) could significantly delay flow separation, thereby reducing drag.

For speed skydivers, aerodynamic optimization consists of finding the optimal length of surfaces: one long enough to reduce pressure drag but short enough to ensure that skin friction does not offset those reductions. The shape of a bullet (half sphere with a cylinder) has a Cd of approximately 0.3. If speeders can clean up their shapes to this value it could theoretically push their terminal velocities well past 600 kmh.

While optimizing gear to reduce drag may improve performance, the design options may be impractical, unsafe to implement or too costly to produce. For example, equipment that is constructed of materials that cannot withstand the forces imposed upon them are not viable options. Custom-shaped helmets and rigs might be difficult or impossible to control at high speeds. The forces produced would be amplified during moments of instability, possibly creating risky amounts of torque on the neck. The equipment's geometry could also interfere with or obstruct parachute deployment.

Atmospheric Conditions: Location and Weather

The density of air decreases with altitude and with higher temperatures. Therefore, the hotter and higher the field elevation of a competition site, the more likely competitors will be able to fly faster. The formulas for calculating density altitude and the complex interplay between how quickly a speeder can accelerate and how quickly the atmosphere gets thicker are too lengthy to go into here, but for elite-level competitors, a 500-meter (1,600 foot) increase in field elevation generally correlates with a 3% increase in maximum velocity. Therefore, competitors love jumping in the early afternoon at sites with high field elevations and hot climates from aircraft that can reach 13,999 feet AGL. Training in this type of environment helps athletes build the skills necessary to capitalize on the good fortune of competing in ideal conditions.

Consistency: Performance Repeatability

Standard deviation is a valuable training tool that measures how dispersed data is in relation to the mean. A low value indicates consistent performance with minimal variation in results across training sessions or competitions. Utilizing this metric can help identify areas of improvement, monitor progress and compare athletes.

The formula for sample standard deviation is as follows:

$$s = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \overline{x})^2}{N-1}}$$

- s = the sample standard deviation
- N = the number of observations
- xi = the observed values of a sample item
- $\bar{x}$ = the mean value of the observations

There are several tools and programs available for analyzing performance. At present, only two programs have official International Skydiving Commission approval for judging purposes—SKYDERBY and InTimeScoring— but they do not provide an athlete with the analytics necessary for training. Several speeders have developed their own to track and monitor progress. While there may be some minor discrepancies between results of these programs, these training aids are extremely valuable when used consistently.

Speed Skydiving's Final Frontier: The 600 Club

Is breaking 600 kmh (373mph) in competition parameters even possible? The 2026 FAI Speed Skydiving World Championships will take place in October at Skydive Arizona in Eloy; a great place and time to go fast. What will speed skydivers achieve? Will there be an "aero arms race" where athletes focus on improving their drag coefficient once they have reached their full potential with regular equipment? The hurdles for equipment innovation are plenty, but tackling just one of these variables may open the door to new possibilities. New talent and ideas are emerging all the time that may very well lead to someone breaking into the 600 Club.

Looking for more information about Speed Skydiving?

- August 2023 *Parachutist* "Who Says Solos Can't Be Fun? The Challenge of Speed Skydiving"
- USPA Skydiver's Information Manual Chapter 5-11: Speed Skydiving
- USPA Skydiver's Competition Manual Chapter 15
- International Speed Skydiving Association at issa.one

About the Author

Niklas Daniel is an ISC Speed Skydiving Committee Member. In 2024, he became the Fédération Aéronautique Internationale Speed Skydiving World Champion, ISSA World Cup Series Champion and USPA National Champion. He is co-founder of AXIS Flight School, which specializes in coaching body- and canopy-flight skills at Skydive Arizona year-round.