FOUNDATIONS OF FLIGHT
FLIGHT DYNAMICS – PRIMARY AND SECONDARY EFFECTS

Brought to you by Niklas Daniel and Brianne Thompson of AXIS Flight School at Skydive Arizona in Eloy. Images by Bruce Fournier and Niklas Daniel. For more skydiving educational content and professional coaching services, visit axisflightschool.com.

Flying a parachute is not complicated. Look right, pull right, go right … right? Well, yes. But there is a bit more to it than that. In the previous installment, we defined the three principal axes and their associated movements. Building on that knowledge, we now take a closer look at how movements are practically applied.

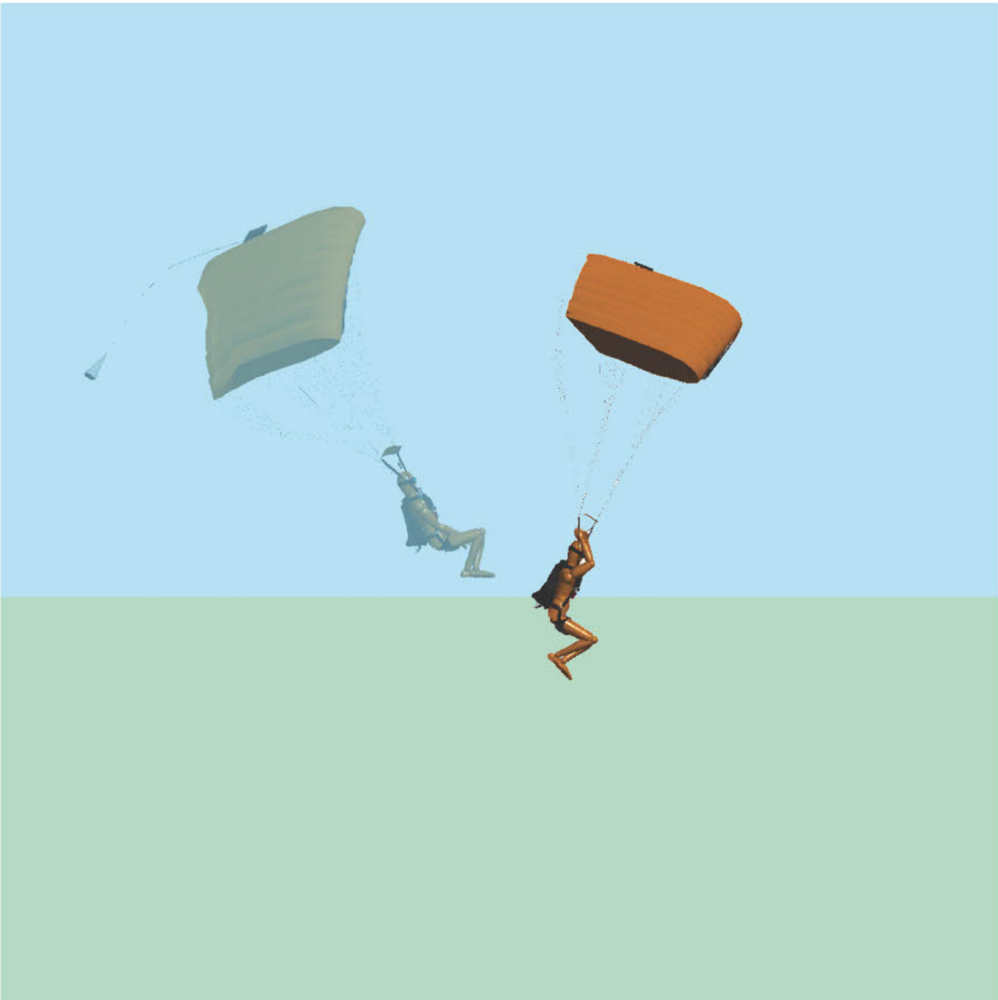
Unlike airplanes, which can manipulate each axis of rotation independently, sport parachutes have limitations. It is not as simple as, "Pull a toggle and the parachute will yaw." Inputs that cause rotation have primary and secondary effects on a parachute system. This is because an initial input made by the pilot is augmented by the inertia of their body hanging underneath the wing. The shorter the suspension lines, the closer the pilot is located to the wing. Smaller canopies are shorter pendulums; therefore, their periodic motion reacts more quickly to inputs for both pitch and roll. The weight of the pilot does not influence the period. This means smaller parachutes require more skill and experience to fly, regardless of wing loading.

Pitch

Symmetrical inputs of the brakes or risers introduce pitch changes. These reshape the wing and alter its airspeed. The pilot's body shifts location under the wing, swinging longitudinally (forward/backward). The pilot experiences a centrifugal force which makes them feel momentarily heavier than they would in steady flight. Pitch alters a wing's angle of attack, which affects how much lift the wing generates. The secondary effects of pitch are alterations in airspeed and decent rate.

Forward Surge

If a pilot flies in deep brakes and then raises their hands up quickly, the system's response is a forward surge—a sudden pitch change from nose-high to nose-low attitude. The pilot feels lighter in the harness momentarily as the wing accelerates overhead, causing the suspension lines to be under less tension. Surging the wing causes the system to be less stable. If performed recklessly or in an uncoordinated fashion, surges can cause line twists.



More educational skydiving content, as well as this free article, is available by visiting axisflightschool.com.

Roll and Yaw

While pitch movements can be isolated, yaw and roll controls are coupled in a complex manner. During a right toggle turn that was starting from steady full flight, the right side of the parachute slows down in relation to the left. This speed imbalance initiates a turn to the right. But the turning event has only begun. Because the body has greater inertia than the wing, the pilot is forced toward the outside of the turn.

A turn is the result of a combination of rotations around multiple axes. The level of response and primary rotation type depends on the speed of the input, i.e., how quickly the pilot moves their hands. When initiated from steady flight, turn rate and descent rate are interdependent. Here are some examples using toggle inputs:

1 | Slow (Roll follows Yaw): During a braked/flat turn, the goal is to change heading while losing the least amount of altitude possible. The pilot uses slow, deliberate toggle inputs to keep their body under the middle of the wing. The primary effect in this instant is yaw. The tendency of the wing to roll as a secondary effect cannot be avoided but must be mitigated. The hands of the pilot are offset very little, and the turn requires patience to be executed successfully.

2 | Fast (Yaw follows Roll): A "yank and bank" causes one wingtip to dip down quickly; ergo, the primary effect is roll. It is the pilot's inertia that then introduces yaw as the secondary effect by swinging the pilot out toward the side of the wing. Quick turns with a tight radius result in fast descents, because banking introduces a horizontal component of lift that tilts the total lift toward the inside of the turn. In doing so, the pilot reduces the total available lift to oppose gravity.

The pilot's body takes time to swing back underneath the wing once a turn is countered or input released. This action is called a recovery arc and represents the path the system travels to home in on its trim speed/ steady flight. The recovery arc can be thought of as a tertiary effect where the system recovers naturally by pitching nose up out of a dive. Like a pendulum, a parachute system swings back and forth until it stabilizes. Similarly, a pilot may overshoot their equilibrium position under the wing after a dive and experience a momentary climb as a result. This is followed by a repeating series of ever-smaller surges and level outs with accompanied speed changes, until the system is fully recovered to steady flight. In flight dynamics this phenomenon is called "phugoid," but is often referred to in skydiving as a "parachute flight cycle." In essence, the system experiences a repeated exchange of airspeed and descent rate. Due to a parachute's intrinsic stability, the flight cycle is a negative feedback loop. It is vital that a pilot has ample altitude for the system to recover from a dive or risk impacting the ground at high speed. There are techniques that make it possible to force the system to recover in a shorter period and less altitude than it would naturally. Jumpers should learn these under the guidance of a canopy coach.

A myriad of different maneuvers can be produced resulting from a combination of control range (the distance your hands move) and input speed. The best control input is the one that is appropriate for a given situation and the pilot's desired outcome. Fast dynamic inputs are not superior to slow ones or vice versa. The decision to utilize one input over another must include variables such as altitude, sink rate, angle of attack, airspeed, attitude and many more details pulled from your situational awareness.

Information about AXIS' coaching and instructional services is available at axisflightschool.com. The author intends this article to be an educational guideline. It is not a substitute for professional instruction.