



Aerobatics: G-Force—The “5th” Force

By Ben Chiu with Patty Wagstaff

G = Gravity

As a Private Pilot, you're no doubt very familiar with the four forces of flight; lift, weight, thrust, and drag. As an aerobatic pilot, one needs to become more familiar with the causes, effects, and management of G forces.

A simple technical description for G force (or “G”) is the force of acceleration of gravity on earth. But for all intents and purposes of our discussion, a G is your weight. One G equals 1 times your weight. Ten G is 10 times your weight.

Although G's are referenced to gravity, and the influence of gravity can increase or decrease G loads depending on your aircraft's orientation and direction of travel, G's can be generated/experienced at any attitude. A simple example that can help illustrate the principle behind G forces is imagining you were swinging a rock tied to a string in a circular path over your head. The faster you swing the rock, the heavier it'll feel (apparent weight). The string represents centripetal force (the holding force), and the force that keeps the string taut is centrifugal force.

If we replace the rock from our example with an airplane, and replace the string with the lift generated by the wings of the airplane, you'll begin to see how the relationships between centripetal and centrifugal force work together. (See Figure 1.) While centrifugal force acts independently from gravity, it can reduce or increase gravitational effects as we've discussed in our Energy vs. Gravity discussion. For example, at the top of a loop, centrifugal force reduces the effects of gravity. Conversely, on the bottom of the loop, it increases its effects.

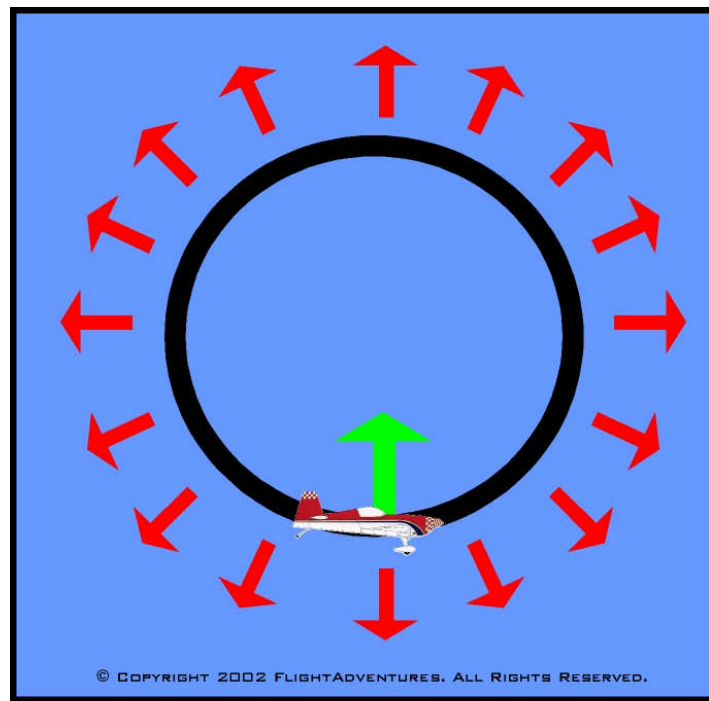


Figure 1: In a loop or high-G turn, centrifugal force (red arrows) is counteracted by the centripetal force generated by positive lift (green arrow).

What's also important to note is the lower your airspeed, the fewer G's you'll be able to generate. This is simply because your wings won't generate as much lift. Also, if you pull back on the stick less, you'll generate (or “pull”) fewer G's for the same reason.

In military fighter pilot circles (pardon the pun!), an aircraft's performance “sweet spot” where its minimum airspeed produces the maximum G is known as *corner velocity*. (See Figure 2.) Corner velocity is important to fighter pilots because it produces the tightest turns (highest turn rate and smallest turn circle.) For aerobatics, it's important to know this number as well because if you're flying

below cornering speed you won't be able to produce maximum G and extract maximum performance from the aircraft.

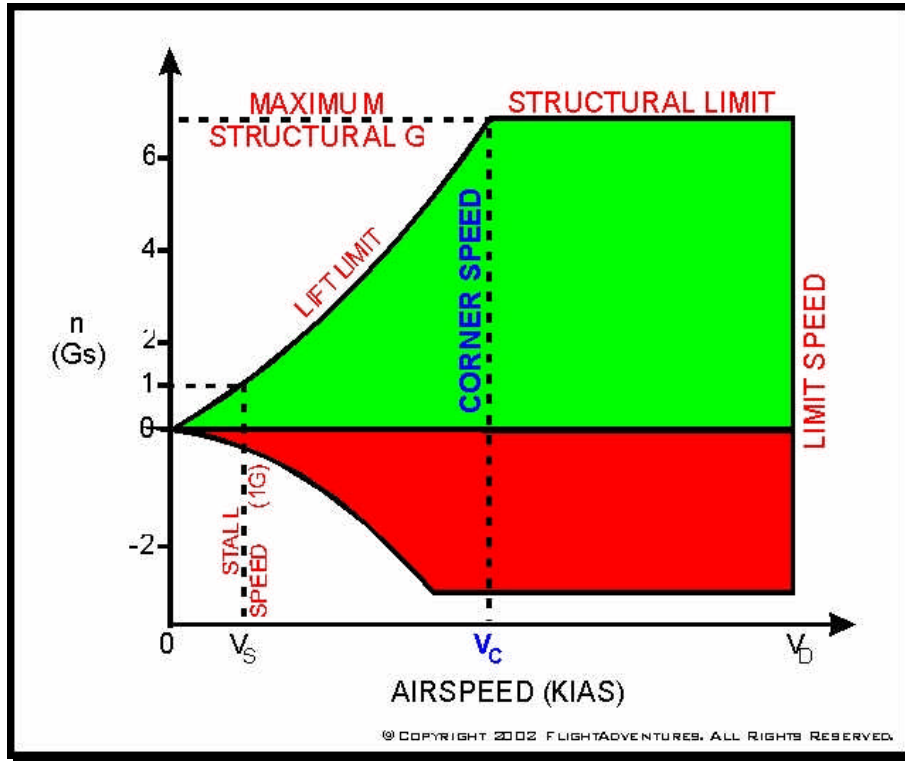


Figure 2: Corner velocity is the point where lowest airspeed produces maximum G.

G's in Aerobatics

During air combat maneuvering fighter pilots normally experience 9+ G. Conversely, top aerobatic pilots can experience greater than 10+ G. (Unlimited-class aerobatic aircraft can sustain more G (+/- 12g), which is more than most modern fighters. This is typically because fighters are heavier and have to carry a lot of extra weight such as ordnance, etc..)

This isn't to say that top-tier aerobatic pilots are in better shape than their military counterparts or anything like that. Any pilot can sustain relatively more G's over a short period of time. This is simply because less blood can leave or enter your head in a shorter period of time. Three-time U.S. Aerobatic Champion, Patty Wagstaff says, "A sustained 3-4G turn is much harder to deal with than a short, instantaneous 9G turn."

Little-Known Fact: While transporting her Extra 260 to its current home at the Smithsonian in Washington, DC, Patty Wagstaff pulled 12G in it and left the reading on the G meter. "I knew it was the [airplane's] last flight so I thought it was OK to do that," says Patty.

Effects of G's

G forces are classified as either positive or negative. In aircraft, the defining criterion is the relative direction in which lift is normally generated (upward perpendicular to the wings). In level, un-accelerated flight you'll be subjected to 1 G. Suddenly increasing lift (pulling back on the stick) will result in positive G's, and suddenly decreasing lift (pushing forward on the stick) will create negative G's. (See Figure 3.)

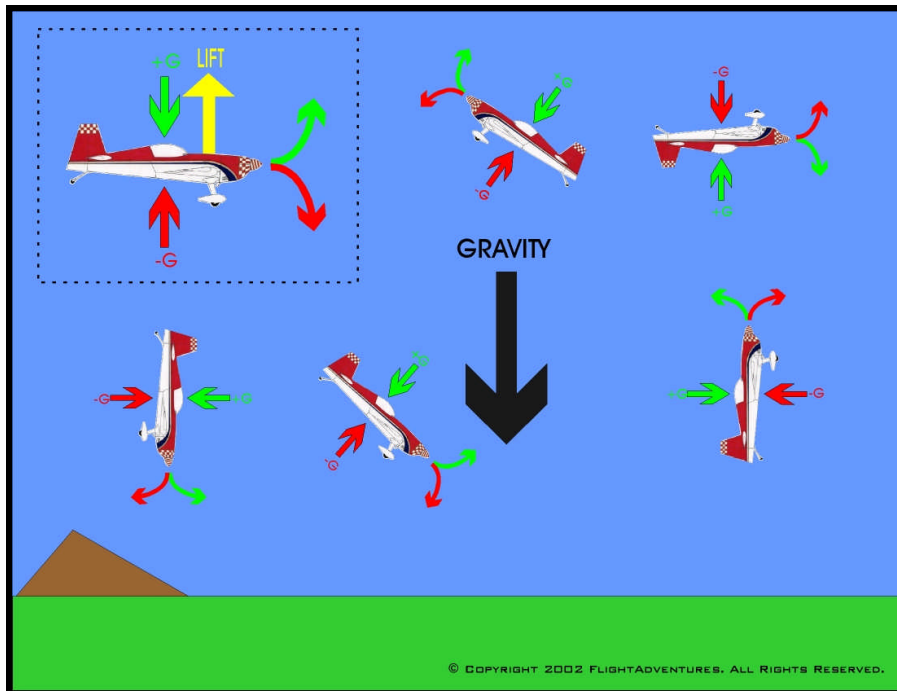


Figure 3: Regardless of aircraft attitude, G forces can be positive or negative based on which direction they act in relation to normal lift in level, un-accelerated flight.

While the effects of excessive G loads on your aircraft can result in structural failures, excessive G loads on your body can also cause serious damage. The dangers of excessive positive G exposure include graying out, blacking out (GLOC—G-induced Loss of Consciousness, which is more dangerous because you're unconscious so you're no longer controlling your aircraft), broken blood vessels in the eyes (broken capillaries), “G-sels” on your skin (named in jest after measles because they look like little red spots). G-sels tend to appear on the faces and heads of aerobatic pilots due to negative G's, and on the legs of fighter pilots from positive G's.

Conversely, excessive negative G's can cause inner ear problems and cause you to lose your sense of balance. This type of vertigo is known as the “wobblies” among aerobatic pilots. Other symptoms of exposure to excessive negative G's are headaches and earaches.

Excessive negative G's can also produce the “stupid,” which is a lowering of cognitive levels where the pilot can't think and “feels kind of dumb.” Patty says that the stupid, “tend to be more of a problem at the beginning of the season when you're not in condition for the G's, but later in the season it's not an issue.”

Dealing with G forces

With positive G's, a pilot needs to fight to keep the blood in his/her head. One technique used to do this is called the *Valsalva maneuver*. This is the same breath holding technique used by power weightlifters, which helps create intra-abdominal pressure, producing resistance, so blood has a harder time leaving your head and entering your body. (Figure 4.) You may have heard fighter pilots “grunt” during high G maneuvering. This is what they're doing.

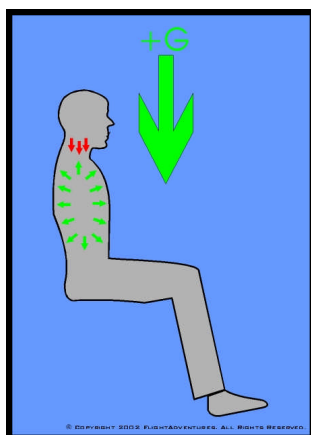


Figure 4: The intra-abdominal pressure created by the Valsalva maneuver helps keep blood from leaving your head when pulling positive G's.

As for negative G's (which are universally regarded as the most difficult to deal with), the only thing you can do is not tense up. Tensing your body up with the valsalva maneuver in a negative G situation will work against you because it will increase the blood flow to your head—which would be very painful and could be dangerous.

Tip: Patty says, "Sukhoi's tend to be a little non-linear on the controls so there's a tendency to push higher negative G's in those."

For you older pilots, there's evidence that older pilots have better G tolerance. Whether this phenomenon is due to age-related factors such as hardening/loss of elasticity of the arteries, slower metabolisms or simply years of repetition is not known.

G-tips from a G-Whiz, Patty Wagstaff

What can be done to build your resistance to the effects of G? There are many rumors that float around aerobatic circles such as eating more junk food, and smoking will increase your G tolerance. If you've been around aviation for any period of time, you get used to listening to hangar talk with a grain of salt. So what's a budding akro pilot to believe? Patty Wagstaff offers these tips:

- Conditioning is the best for building G tolerance, and the best conditioning comes from simply pulling G's. Keeping in shape will help your conditioning. Weight training is best because anaerobic exercise is better than aerobic exercise for G conditioning. This is because with aerobic exercise your arteries become more efficient, and that allows your blood to travel with less effort, which is what you don't want.
 - Keep hydrated by drinking lots of water and non-alcoholic fluids. When you're dehydrated, your blood gets thicker, which makes recovering much slower.
 - Eat before pulling a lot of G's. An empty stomach degrades your G tolerance.
 - Pulling G's also lowers your blood sugar, so drinking juice or eating something high on starch and sugar before or after you fly can help.
 - Respect yourself. If you are tired and don't feel like pulling or pushing as hard, listen to what your body is telling you.
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Fact: It can be said that the effects of G can be considered to be cumulative because resisting G forces is tiring. So depending on your conditioning, you may not be able to resist as many G's as your routine continues.

Factors that can reduce your resistance to the effects of G include:

- Smoking
 - Lack of sleep
 - Hangovers
 - Dehydration (which is believed to cause hangovers, but can be experienced without alcohol intake)
 - Bugs/illness and food poisoning
 - Not eating before a flight
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