What is Neutral CG? by flying ferret

The balance point at which aerobatic planes behave in an uncoupled manner Commonly called the 'sweet spot'. Trim for level flight, roll inverted, and the plane continues on its path. Put it in a dive & it doesn't pull out on its own. Rather, it simply continues on the path until you command it to do something else. Best aerobatic performance is achieved with the **CG** at the neutral-handling point.

Here's a tutorial I wrote on the topic of tuning the **CG** for optimal handling:

For those who are new to the world of purpose-built aerobatic planes, I decided to post the following information on flight-trimming:

*Aside from creating an unflyable condition, **CG** settings are largely a matter of preference. However, many pilots find that with purpose-built aerobatic ships, adjusting the **CG** for neutral or near-neutral handling usually works best for all-around aerobatics & precision flight, while a slightly aft **CG** usually works better for 3D, and a slightly forward **CG** typically improves stability & tracking - which may be desirable when flying in turbulent air. Understanding the effects of flight-trimming & **CG** placement, plus experimenting to find the settings that work best for a given airframe and flight condition, will allow the pilot to optimize most any airframe to suit one's purpose and flying style.*

*The neutral handling point, or **CG** 'sweet spot' as it is called by some, is the balance point which provides neutral pitch stability. No pitch-change with changes in throttle or airspeed. No pitch change when rolled to knife-edge or when rolled inverted. When balanced at this point, an aerobatic plane simply goes where it's pointed until commanded to do something else. Pattern planes are usually balanced at or slightly forward of the sweet spot. 3D planes are usually balanced at or slightly aft of the sweet spot. The manufacturer's recommended **CG** range for most trainers & sport planes is typically well-forward of the sweet spot. Assuming that the airframe is straight & true, adjusting the **CG** in small increments will allow one to tune the plane's behavior.*

I will attempt to explain what's going on in non-technical terms.

First off - my comparisons below assume we are talking about a purpose-built aerobatic plane or aerobatic sport-plane with a symmetrical or semi-symmetrical airfoil (not a Cub). One that is properly built - correct thrust-line, wing incidence, tail alignment, etc.

Nose-heavy:

All else being equal, the slightly nose-heavy plane will be less sensitive in pitch & yaw than a neutrally-balanced or slightly tail-heavy plane. The nose-heavy plane will also have to fly faster & land faster to prevent stalling. These two factors are largely responsible for the improved wind penetration vs. the neutrally-balanced or slightly tail-heavy plane. Unfortunately, they are also detrimental to slow-speed flight. The nose-

heavy plane will have more drag in level flight at a given airspeed, and will therefore require more power to maintain cruise speed. Additionally, the nose-heavy plane will usually have a lot more throttle/pitch coupling. If it's extremely nose-heavy, the nose will drop dramatically during turns, or when power is reduced. There may not be enough elevator authority to establish a power-off glide. It may also be impossible to flare during a power-off landing. Conversely - when power is applied, the nose-heavy plane will tend to pitch up. During knife-edge, the nose-heavy plane will tend to pull to the canopy, unless down-elevator is used. These things happen because the nose-heavy plane requires a certain amount of up-elevator trim for level flight at a given airspeed.

*Compensating for a forward **CG** with elevator trim causes the plane's behavior to change as the power setting or flight angle changes, because the trim required is dependent on speed and flight angle. For instance, if up-trim is required for level flight, when rolled inverted, the up-trim becomes down-trim, which is the opposite of what is needed, so the plane dives. In KE flight, that up-trim turns into "side-trim" which makes the plane pull towards the canopy. The extra nose-weight is now acting on the yaw axis, and is being compensated with 'top rudder', so the up-elevator trim now pulls the plane toward the canopy. A change in speed will change the effectiveness of the up-trim, which will make the plane pitch up as power is added, and pitch down as power is cut. (Note: most trainers and many sport & scale general aviation planes will also tend to climb/dive when power is added/cut, but in these cases, the behavior is to be expected.)*

*Most full-scale general aviation planes are balanced somewhat forward of the neutral point for safety/stability. RC trainers & sport-planes are also designed to be very stable, and usually specify a forward **CG**.*

Neutral CG:

The neutrally-balanced plane will usually have very little (if any) throttle/pitch coupling. The nose will stay put when power is increased/decreased. The nose will not drop much (if at all) during turns. The plane will also stay level in knife-edge - even without rudder (of course, top-rudder will still be required to maintain altitude). Also - there will be little, if any rudder/pitch coupling during knife-edge. Slow-flight will be much improved, and establishing a shallow power-off glide will be much easier - as compared to the same plane in nose-heavy trim. Very short landings are also easier, as there will be plenty of elevator authority to come in a bit nose-high, and then flare at touchdown. Aerobatic maneuvers become much easier, as the neutrally-balanced plane has no tendency to self-recover. Put it into a climb or dive, and it will stay on track until commanded to do something else. The nose will stay put regardless of power setting. When trimmed for level flight, the neutrally-balanced aerobatic plane will fly level inverted with little, if any elevator input, and should fly a knife-edge pass with no tendency to pitch toward the canopy or tuck to the belly.

A plane that is balanced at or very slightly forward of the neutral point will typically be well-suited for precision aerobatics. This is where pattern planes are usually balanced. Purpose-built full-scale aerobatic planes may also be balanced close to the neutral *point. For less-experienced RC pilots, the neutrally-balanced plane can be challenging to fly. For instance, the nose doesn't drop as the plane slows down; the plane usually descends in a level attitude, and may stay level after it stalls - or iit may suddenly drop a wing if aileron input is given. Hence, there are typically no visual clues of an impending stall. When put into a dive, the neutrally-balanced plane will not self-recover; it will continue on the path until the pilot gives some stick input. Same is true for climbs.*

Note: With flat-plate and symmetrical airfoils, a certain amount of trim is required for level flight because they must fly at a positive angle of attack to generate lift (unlike semi-symmetrical, flat-bottom, or under-cambered airfoils). Therefore, when trimmed for level flight & rolled inverted, they will require a hint of down-elevator for level inverted flight - even though the ***CG*** *is set at the sweet spot.*

Tail-heavy:

The slightly tail-heavy plane will excel in 3D maneuvers - especially harriers, elevators, flat-spins, hovering, tail-slides, and tumbling maneuvers. Precision flying usually suffers due to the effects of negative pitch stability. Pitch-instability will cause the tail-heavy plane to become extremely sensitive to elevator input. Throttle/pitch coupling will also return, but the effects will be reversed as compared to the nose-heavy scenario: When trimmed for level flight, the slightly tail-heavy plane may have a tendency to tuck its nose when power is applied, and will tend to balloon when power is cut. It will also have a tendency to pull to the belly during knife-edge. When trimmed for level flight and then rolled inverted, the tail-heavy plane will usually climb. These things happen because the tail-heavy plane requires a certain amount of down-elevator trim for level flight at a given airspeed.

Compensating for an aft ***CG*** *with elevator trim causes the plane's behavior to change as the power setting or flight angle changes, because the trim required is dependent on speed and flight angle. For instance, if down-trim is required for level flight, when rolled inverted, the down-trim becomes up-trim, which is the opposite of what is needed, so the plane climbs. In KE flight, that down-trim turns into "side-trim" which makes the plane tuck towards the belly. The extra tail-weight is now acting on the yaw axis, so the down-elevator trim now pulls the plane toward the belly. A change in speed will change the effectiveness of the down-trim, which will make the plane drop the nose when power is added, and pitch up when power is cut.*

A bit more tail-heavy, and the plane may become so unstable in pitch that it is impossible to fly. Some airframes are more forgiving than others in this respect. For instance, the UM ***Sukhoi*** *has a very wide flyable* ***CG*** *range. It will fly with the* ***CG*** *anywhere from 25mm (extremely nose-heavy - very poor flight performance), to 42mm (definitely tail-heavy - wild 3D, but a real handful to fly). Some airframes are not at all forgiving with* ***CG*** *placement. Some may immediately crash after take-off when they're even moderately tail-heavy. Others may remain flyable until they're put into certain situations, such as a spin - and then become completely unrecoverable.*

Although full-scale planes are usually designed to be balanced for positive pitch-stability - or in the case of purpose-built aerobatic planes, near-neutral pitch-stability, there are exceptions. Many fly-by-wire fighters and most, if not all of the thrust-vectoring fighters are purposely designed to be aerodynamically unstable so they can do wild, uncoupled flight maneuvers. The flight-control computer(s) sort it all out for the pilot.

Trimming aerobatic RC planes:

*It has been said that a nose-heavy model may fly poorly; however a tail-heavy model may fly only once. For the most part, it's true. It's best to start out toward the nose-heavy side of the manufacturer's recommended **CG** range, and then sneak up on the neutral point.*

*The main problem with tuning RC airframes for one's desired flight characteristics is that many of the adjustments are interactive, and some parameters have similar symptoms when they're out of adjustment. Things must be checked/adjusted in the proper order - otherwise the process can become quite frustrating. The guide below will allow the pilot to sort out various handling issues in a scientific manner. Courtesy of the **NSRCA** (National Society of Radio Controlled Aerobatics):*

http://nsrca.us/index.php?option=com_content&view=article&id=177:trimchart&catid=114:flying&Itemid=187

See the attachment for a printable version.

Remember - the guide above is intended to be used for flight-trimming purpose-built aerobatic planes, or at least aerobatic sport-planes. It is not intended to be used for trimming scale general-aviation planes like Piper Cubs & such, warbirds, RC trainers. These aircraft are usually designed to have at least some positive pitch-stability. For instance, one would not expect neutral behavior from a J-3 Cub. The experience of flying a tail-heavy warbird is not something you really want to have. That said, the general flight-trimming rules still apply. For instance, a nose-heavy GA plane or warbird will drop the nose excessively in turns or when power is cut, and it may lack the elevator authority to execute a power-off flare.

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