GYROPLANE STABILITY MISCONCEPTIONS – Part 1
OR
The “REST OF THE STORY”

By Greg Gremminger

Greg Gremminger is chairman of the ASTM Gyroplane Light Sport Aircraft subcommittee developing the Design and Performance standard for light sport gyroplanes. He is a member of the Popular Rotorcraft Board of Directors. He has flown general aviation and Experimental aircraft for over 30 years. He has built and flown various ultralight airplane models over a 15 year period. He has built and flown gyroplanes for 18 years, including re-designs to experiment with and incorporate various stability enhancement features and principles. Gremminger is currently the U.S. Distributor for the Magni line of gyroplanes produced in Italy.

Many of you might consider what I am about to say as “blasphemy.” But, I’m going to say some things about stabilizers, thrustlines and stability, which may not totally agree with some popularly espoused concepts on these subjects. Essentially, gyroplane stability technology has advanced, and is now becoming more understood, beyond the old popular and often misleading “cook book” concepts.

Most popular solutions to unstable gyros (and PIO and buntovers, etc.) are certainly valuable guidance and have improved the safety of the gyro sport. For instance, it IS a very good thing to have a large and effective Horizontal Stabilizer (HS). It is also a good thing to have a propeller thrustline that is reasonably aligned with the CG of the aircraft. However, these popular “cook book” solutions can be a bit misleading as to what they can do and how well they can do it. The true stability and safety of a gyro can not be insured by simply following one or more “cook book” solutions. In fact, some popular “cook book” solutions, or poor combinations of these solutions, can actually present other, even less apparent safety issues.

The purpose of this article is two-fold: To make sure gyro pilots won’t have misplaced confidence just because they use one or more of these popular “cook book” solutions. Pilots should still understand the limitations of their particular gyro configuration, with perhaps some unexpected traits, and the proficiency required to operate that gyro. The second point of this article is to correct some of the inferences about prop thrustlines and HS configurations that are not technically supported and can even influence much less than optimal control, stability and safety.

While presenting a number of downsides of popular misconceptions, be assured that a proper design can actually provide gyroplanes that exhibit few or none of these downside issues. This article is just to make you aware and avoid falling into “over-confidence traps”. When designed properly, as verified by actual flight testing, gyros can present stability and transient safety margins well beyond those capable on even fixed-wing aircraft.

Misconception #1: **“Centerline Thrust (CLT) is best”**: Although a much better idea than a highly offset and “unbalanced” prop thrustline, CLT is certainly not the ideal or only thing to do. “CLT” can certainly be a desirable condition, but designers should consider some issues:

- Most people consider any "high seater" gyro as CLT. Often these may really be "low prop thrustline" not a true "CLT." A low prop thrustline can present some less than optimal flight characteristics itself – See Misconception #2 below.
- There are very few true CLT gyros! Burn off some fuel or carry a heavier pilot, and the Vertical CG (VCG) has moved, and is no longer aligned exactly with the prop thrustline. The rest of the gyro design should allow for these variations – not depend totally on "CLT".
- A perfect CLT without a HS has only neutral static stability – not positive static stability. CLT, alone, does nothing for dynamic stability – PIO is the critical dynamic stability issue.
- A perfect CLT with a HS may not be Power Stable at the same time as Airspeed and G-Load statically stable. A perfect CLT may not, on its own, position the Rotor Thrust Vector aft of the CG. A down-lifting HS must be arranged to provide this nose-up moment to the airframe in order to achieve Airspeed and G-Load positive static stability – CG forward of the RTV. But the down-lifting HS (a very good thing!) is may not be compatible with a CLT that does not provide a balance to the nose-up moment from the HS. This means the airspeed can change as a function of power setting – not Power Stable. This may not be totally bad if not severe, but it can get novice pilots into trouble upon sudden power changes such as in a botched landing or engine failure – the nose attitude can change dramatically and excessively!.
- A perfect CLT with a HS that does not provide a down-lift moment likely has only neutral static stability in airspeed and G-load. Even though the HS may provide dynamic stability, the lack of static airspeed and G-Load stability requires additional skills and workload from the pilot. Lack of positive airspeed and G-load static stability are critical issues in buntovers and can initiate PIO!
- Reliance on assumed CLT for stability does not consider an airframe drag line offset (from CG), and other nose-down aerodynamic moments that likely might statically destabilize the gyro.

Misconception #2: **"A Lower Propeller Thrustline is Better!"** A propeller thrustline that is significantly below the gyro VCG should not be confused with Centerline Thrust (CLT). The significant nose-up moment from a low prop thrustline actually does dramatically improve the G-Load stability of the gyro - by rotating the in-flight attitude more nose-up to position the RTV further aft of the CG – but only when significant power (thrust) is applied. This is a great thing for G-Load static stability and for high speed flight stability and wind insensitivity! This is called "power augmented stability", but it has much less effect when power is low. The problem is that this enhanced G-Load static stability is present only when significant power is applied. When lower power or idle or no power is present, the nose is not artificially held at such a high attitude and the RTV is not so far aft of the CG. In fact, other configuration issues may drag or push the nose down and the CG aft of the RTV – static G-Load instability, the root cause of buntovers. The issue this presents is that a different pilot proficiency is required to fly at high speed and low power safely, as compared with the stability and ease of control when power is higher on that same gyro.

A second issue with this configuration is that a low prop thrustline actually forces the HS to present an up-lift to balance the nose-high, high power condition. An up-lifting HS may not provide static airspeed stability, in other words, the airspeed continuously tries to diverge from the set or "trimmed" condition - and "active" pilot control is required to maintain the airspeed balanced at the trimmed airspeed. If airspeed is allowed or forced to change significantly above or below the "trimmed" airspeed, stick forces attempt to further increase that deviation. An airspeed statically stable gyro would always attempt to self-return to the "trimmed" condition.

A third issue with this configuration is that a change in power significantly changes the “trimmed” airspeed. That means that it takes forward stick pressure to maintain the same “trimmed” airspeed in a higher power climb as compared to cruise power at cruise “trimmed” airspeed. In other words, to climb at the same airspeed, forward stick pressure is required. The opposite happens with reduced power. This becomes a more serious issue when rapid changes in power are made – such as in landing or a botched landing. This also presents a possible buntover or precession stall issue upon rapid power changes (sudden reduction or loss of power) – the rapid nose down rotation from loss of nose-up thrust, coupled with the tail-up force of the HS, can cause the RTV to move rapidly forward of the CG and possibly precipitate a buntover or rotor precession stall. This may not be the priority buntover issue among gyros, in fact the augmented stability of such low prop thrustline gyros may have dramatically improved the safety of gyros overall – much more stable at high speed in gusty winds! But, pilots should appreciate the potential for these other, less apparent safety issues. At high speed, a sudden reduction of power might initiate a transient pitch reaction beyond which the pilot skills are adapted or experienced.

Misconception #3: **“High Prop Thrustline is Bad!”** Sorry, a slightly high prop thrustline is the reliable way to achieve positive **Airspeed Static Stability**, positive **G-Load Static Stability**, and good **Power Stability** - at the same time. It is true that the “high prop thrustline” must be “balanced” by a properly configured HS, but, to reliably assure all three static stabilities, a gyro’s HS must have a **down-load** on it in flight. A down-load on the HS forces the CG to be forward of the RTV for **G-Load static stability** and balances the forward CG for **Airspeed static stability**. Just as in airplanes, **Airspeed Static Stability** requires a down-loaded HS. Low prop thrustlines require an actual up-lifting HS which presents a divergent or negative static airspeed characteristic. True CLT requires a near neutral lift HS for Power Static Stability, providing only weak Airspeed and G-Load Static Stability.

A slightly high prop thrustline requires a down-loaded HS (reacting to propwash effects) in order to “balance” the slightly nose-down moment of the high prop thrustline. This down-loaded HS, also reacting to airspeed, should also “balance” the forward CG for static airspeed stability. The down-loaded HS (reacting to both propwash and airspeed) holds the RTV aft of the CG in flight – providing the important G-Load static stability. The inference of this misconception is that high prop thrustlines are more susceptible to Power Push-Over (PPO). This is only true if the high prop thrustline nose-down moment is not reasonably “balanced” by a nose-up moment of the HS reacting to propwash. This “balance” is easier and more efficient if the prop thrustline is not excessively high, but any high prop thrustline can probably be “balanced” with enough down-loaded HS in the propwash! The truly stable gyroplanes are those that have enough “balanced” HS down-load (reacting to both propwash AND airspeed) to hold the RTV steadily aft of the CG (CG forward of the RTV) – at all **power** settings and at all **airspeeds**.

Misconception #4: **“CLT does not require a Horizontal Stab!”** CLT has the issues described in “Misconception #1” above. CLT gyros are not necessarily PIO or even buntover proof! For ANY prop thrustline configuration, passive DYNAMIC Stability in a gyro can only be achieved with an adequately sized HS. **Dynamic** stability is the issue involved in Pilot Induced Oscillations (PIO). PIO can lead to a buntover after a few cycles. CLT, in itself, does not provide dynamic stability!

Dynamic stability characteristics are a function of the inertias (Moments of Inertia) of the airframe and of the rotor, and of the interacting inertial reaction rates of the rotor and airframe. (Dynamic stability is not a function of the propeller thrustline!) The rotor and airframe inertias mostly determine the natural pitch oscillation rates of the whole system. All bodies, including aircraft and gyros, if they are statically stable in some condition, have natural tendencies, upon disturbance, to oscillate around that statically stable condition. If that natural pitch oscillation rate is so quick (short-period) that a human pilot cannot react with the proper amplitude and timing, PIO can be a likely result. With no HS, the pilot must be the "active" stabilizer to "dampen" the pitch oscillations. Especially if the reaction rates of the airframe and rotor "resonate" or build on each other, the pitch oscillation rate, once excited or started by a disturbance, can be much faster than the pilot can correct ("dampen" to zero). With wrong stick reaction inputs, the pilot can readily exacerbate the amplitude of the rapid natural oscillations until they culminate in a buntover. The gyro configuration itself must naturally avoid or effectively dampen such quick oscillation rates. This is not easy to do or determine "on paper" or by some simple guidelines such as a "cook book" size of the HS.

Dynamic stability characteristics are also a function of the HS. The HS provides "passive" (the pilot or autopilot doesn't have to do anything!) damping of the pitch oscillations. "Damping" is required on all aircraft, because all statically stable aircraft will have a natural oscillation at some rate. The HS is what automatically and naturally "dampens" or reduces those oscillations to zero – without pilot action! Typical pilots may be able to "dampen" slower rates of oscillations, but, this requires active reaction (workload) by the pilot. Especially for airframe/rotor inertia combinations that produce very quick natural oscillations in response to a disturbance, the HS must provide aggressive "damping" to very quickly reduce those oscillation tendencies to zero – BEFORE over-controlling PIO reactions are excited in the pilot. The pilot can not be expected to provide the "active damping" required to avoid PIO at higher oscillation rates! PIO is a dynamic stability issue. Dynamic stability characteristics are not a function of the prop thrustline or of the RTV location. A HS is the only proven way, and at least the simplest "passive" way, to provide the damping required to automatically and passively reduce the natural oscillations to zero.

It is simply a fortunate convenience of nature's laws that a HS can both provide the static "balancing" to affect static stability, and the dynamic damping for dynamic stability. Two benefits for the price of one!

<u>Misconception #5:</u> **"The propeller thrustline determines a gyro's stability!"** This is the mother of misperceptions that leads to most of the other misperceptions about CLT and prop thrustlines. The real issue with gyro stability is not the propeller thrustline (relative to Vertical CG) - that is just a part of the real issue. The real issue with STATIC stability is the location of the CG forward of the RTV. This alignment is the result of several static moments acting on the gyro airframe: airframe drag (as a result of airspeed), airframe lift or down-lift (as a result of airspeed), HS down-lift (as a result of both airspeed and propwash), AND propeller thrustline (as a result of engine power). All of these forces acting on a moment arm around the CG of the aircraft determine the overall static stability of the gyro by establishing the static airframe attitude and the position of the RTV aft of the CG. To consider just one or two of these static moments, without considering the effects of all of them, misleads to wrong conclusions about a gyro's stability.

Static G-Load stability requires that the sum of all these moments acting on the airframe results in the CG remaining at or forward of the RTV. G-Load static stability is the prominent issue with buntover risk.

Static Airspeed stability requires that the CG be forward of the RTV, AND that the HS be providing down-lift to balance that forward CG. Airspeed static stability is a secondary issue with buntover risk as it prevents wind gusts from displacing the RTV from it's stable location aft of the CG..

Dynamic stability has nothing to do with the propeller thrustline! Dynamic stability is the result of rotor/airframe inertias and the damping effectiveness of the HS. Dynamic stability is the prominent issue with PIO, which can lead to a fatal buntover (static G-Load instability) after a few cycles.

Static instabilities can lead to pilot over-control and PIO because they present significant and often wrong direction pitch attitude transients that can excite the pilot into over or wrong control inputs. The point is, propeller thrustline is not the only issue – and stability/safety over-confidences based on a "cook book" thrustline solution can lead to poor decisions of what and how and when to fly your gyro. It is difficult to boil these issues down to casually observed "cook book" recipes. The only true way to determine if these critical stabilities are proper is to flight test the result. To pass judgment without flight testing results is to fall prey to the misleading conclusions of this misconception.

In the second part of this two-part article, we will present several more popular, but misleading misconceptions about gyroplane aerodynamics. We will also present another perspective on PIO that might help understand why a gyro should have inherent "passive" stability, rather than relying on the "active" stabilizing skills of the pilot to correctly respond to pitch oscillations that are much to quick for a human pilot to properly "stabilize".

GLOSSARY of GYROPLANE TERMS

The selected terms below are an excerpt from the complete Glossary of Gyroplane terms that can be found at http://www.magnigyro.com/gyroterms.pdf.

Airspeed Stability:

The tendency of an aircraft to self-restore airspeed to the "trimmed" airspeed upon an airspeed disturbance. Typically, the horizontal stabilizer is configured with an amount of down-lift proportional to free airspeed so as to balance the CG located forward of the Thrust Vector (of the rotor or a wing). As airspeed decreases below the "trimmed" airspeed, the down-lift of the horizontal stabilizer would also decrease, allowing the nose to lower and restore airspeed to the "Trimmed" airspeed. Vice-versa upon an increase of airspeed. The amount of down-lift (or the incidence angle) of the horizontal stabilizer typically helps determine the "trimmed" airspeed. *See also "Power Stability" and "G-Load Stability."*

Centerline Thrust – CLT:

A gyro configuration which has the propeller thrust passing through or very near the vertical center of gravity (VCG) of the aircraft. This minimizes the static pitching moments on the aircraft due to propeller thrust.

G - Load Stability:

The tendency of an aircraft to restore any g-load disturbance or variation back to the original 1g loading. Any disturbance, wind or flight path change, will change the g-load of the aircraft – it's effective weight. G-load stability infers that the attitude of the rotor disk and its resultant lift force will self-adjust to restore the g-load back toward normal 1g. In a gyroplane, g-load stability means that the Rotor Thrust Vector (RTV) is physically located aft of the CG of the aircraft. This is verified in flight testing by increasing the g-load on the aircraft by establishing a steady bank, and verifying that aft stick pressure is required to maintain the original straight and level trimmed airspeed. In the banked and turning flight, the CG located forward of the RTV, causes the nose to pitch lower, requiring aft stick pressure to maintain original airspeed. This is analogous to g-load stability in an airplane that also requires the CG to be forward of the Thrust Vector of the wing. Gload instability would be indicated by the requirement to provide forward stick pressure to maintain original straight and level airspeed while in a banking turn. G-load instability would result in divergent pitch and airspeed resulting from a g-load disturbance – upon reduced g-load in a down gust for instance, the nose of the aircraft would drop, further reducing the g-load on the aircraft and continuing this process to increasing nose-down pitching. *See also "Airspeed Stability" and "Power Stability."*

Power Stability:

The tendency of an aircraft to maintain a reasonably fixed airspeed upon changes in engine power. To be considered "power stable", an aircraft should maintain "trimmed" airspeed at all power settings with minimal pilot control stick pressure or displacement. *See also "Airspeed Stability" and "G-Load Stability."*

Stability:

The property of an object or system that self-maintains or self-restores that object or system steady state or equilibrium. A stable object or system will maintain equilibrium and will self-restore equilibrium if disturbed. An example of stability is a ruler hung from one end – when disturbed from vertical, it restores itself to its original vertical hanging position and remains in that steady state hanging position – disturbances do not cause it to "fall over" as it would if it were balanced on the other end. Restoration to equilibrium is accomplished without external control or effort. *See also "Instability," "Positive Stability" and "Negative Stability."*

Static Stability:

The property of a system or object to self-restore to equilibrium or steady state condition upon a disturbance. For aircraft, static stability is the tendency to return to trimmed attitude after a disturbance is introduced. The tendency to return to equilibrium can go too far, resulting in overshoot of the target, resulting in dynamic instability. Static stability infers positive static stability as opposed to negative static stability. *See also "Stability,""Dynamic Stability," "Positive Stability" and "Negative Stability."*

GYROPLANE STABILITY MISCONCEPTIONS – Part 2
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In the previous installment of this two-part article, we discussed five popular misconceptions about propeller thrustlines as they relate to gyroplane stability. This Part 2 discusses some other popular, but misleading gyro aerodynamics misconceptions.

While presenting a number of downsides of popular misconceptions, be assured that a proper design can actually provide gyroplanes that exhibit few or none of these downside issues. This article is just to make you aware and avoid falling into “over-confidence traps”. When designed properly, as verified by actual flight testing, gyros can present stability and transient safety margins well beyond those capable on even fixed-wing aircraft.

Misconception #6: **“Air on top of the rotor makes the rotor slow down!”** Air on top of the rotor would actually still provide autorotation in the same direction – maybe not as effectively, so that a 1 G negative load on that rotor might provide an even higher autorotation rotor RPM!! Rotor RPM would still support that negative G load! Blaspheme you say! If you could get air suddenly on top of the rotor continuously, and the control, buntover and coning angle issues weren’t a concern, the rotor would continue to autorotate. (Try turning the airfoil blades on a gyrokite upside down and prove it to yourself.)

The real issue is that reduced G-load on the rotor, between plus and minus 1 G, does slow the rotor down and would probably never allow you to get “air on top” before the gyro starts flapping and hitting things! I’m not saying it is OK to go negative Gs. In fact I’m saying it may be dangerous to incur even somewhat reduced Gs! This may be just academic, the results are still the same, but I think it is important for pilots to appreciate the limits of their machine! The issue is not “air on top of the rotor”; the issue is **reduced** G loads on the rotor (less than 1 G). Some gyro/rotor combinations, due to inertias and degree of G-Load static stability, may tolerate lower and longer reduced rotor G loads than other gyros, but everyone should recognize that they should not present either rapid or prolonged forward stick – purposefully rapidly reduced G load to the rotor. A G-Load unstable gyro might very easily initiate a rapidly diverging forward bunt upon just a sudden reduced G-load – it does not necessarily need “air on top” or “zero Gs” to be deadly! Most rotors can handle some quick and short rotor downloading, such as a wind gust. But, the real issue here is whether the G-Load pitch stability is adequate to prevent an immediate precession stall, buntover, or rotor strike. An adequately statically stable gyro, with complimentary dynamic stability characteristics and rotor inertias, can be VERY resistant to low G buntovers – the airframe and rotor reactions resist commanded rotor unloading and rapidly self-restore rotor loading before the rotor has a chance to slow down too much. But, you can't rely on a "cook book" remedy alone to assure that your gyro has such adequate static and dynamic stability characteristics for the wind gusts you might be tempted to fly in.

Misconception #7: **"Pilots can stop PIO if they chop power** and reduce speed**!"** Partially true, but only for specific gyro configurations – for other gyro configurations, this can be a dangerous reaction. Reducing power rapidly has been a traditional remedy that really only applies to traditional high, unbalanced thrustline gyros. For these gyros, airframe nose-up pitch reaction to suddenly reduced power (Power instability), does cause the RTV to reposition rapidly aft of the CG. This immediately restores static G-load stability, and reverses the required control inputs to a more intuitive direction so that the pilot might more readily dampen dynamic oscillations or stop long-period PIO. For such unbalanced high prop thrustline gyros, chopping power is THE correct thing to do!

But, for a low prop thrustline gyro, the rapid nose-down pitch reaction of a rapid reduction of power could actually initiate an immediate precession stall or buntover, or make the aircraft immediately G-load unstable by rotating the RTV rapidly forward of the CG. In fact, pulling aft on the cyclic at the same time (reducing speed!) also moves the RTV further forward of the CG to further aggravate this transient situation with worse static G-load instability! This rapid nose pitching is also a sharp dynamic transient that could possibly trigger a true short-period PIO. In effect, chopping power on a low prop thrustline gyro can worsen the stability and control issues by changing static stability and initiating a dynamic response or subsequent over-reaction from the pilot.

This popular remedy or misconception may not even be possible for a true and fatal PIO event. PIO can come in different rates. Very quick, or short-period natural oscillations would be difficult or impossible for a human pilot to dampen or stop. These short-period natural and undamped oscillations (probably a 5 second period or less), are probably the precursor of a true fatal PIO.

Slower, long-period oscillations are more readily dampened by the pilot, and probably do not evolve directly to a short-period PIO event. Long-period oscillations or PIO are likely the commonly observed pitch nose "bobbing" of unstable gyros. But, these long-period oscillations would not be expected to suddenly pitch violently and more quickly into a true PIO event. An experienced pilot could learn to control those slow oscillations – thus the old remedy – to stop recognizable slow pitch oscillations.

But, quick, short-period oscillations of a fatal PIO are probably not recognizable or correctable. They happen at such a rate and such severe pitch excursions, that it is probably not possible for a human pilot to stop the short-period, rapid oscillations of a true, short-period PIO event. The point is that quick and fatal, short-period PIO occurs so rapidly that the old remedy probably does not really apply because the pilot may have no time to react at all!

It is my arguable point that the pitch oscillations you can recognize and stop by proper pilot control are not those rapid pitch oscillations of a real, short-period and fatal PIO. I am suggesting that it is not even possible to recognize and stop true fatal, short-period PIO, once it has started. The only true defense to fatal PIO is to provide adequate "passive" damping (an adequate HS) that avoids sustained short-period natural oscillations. The long-period, slow rate pitch "bobbing" often observed is probably not the precursor to a fatal PIO. But a tendency for long-period oscillations ("bobbing") probably does indicate inadequate pitch damping of the HS and that that gyro may be susceptible to the higher rate fatal PIO pitch oscillations.

<u>Misconception #8:</u> **"A CLT or low prop thrustline gyro cannot PPO!"** This is actually true, but only by definition. A true CLT or low prop thrustline cannot be "pushed over" by the prop. But that does not mean it cannot bunt over! A PPO is just one form of a buntover that is described as the prop thrust pushing it over into the buntover. A CLT or low prop thrustline gyro can still buntover – although it might be less likely and under different circumstances, it can still bunt! A dynamically inadequately stable gyro is still subject to PIO (if it has inadequate HS effectiveness). On inadequately stable gyros, a rapid nose-down rotation from either pilot input or suddenly reduced power can re-position the RTV suddenly forward of the CG and result in a buntover – especially if other airframe drag or lift moments cause the airframe to rotate nose-lower than normal flight. Don't abuse any gyro because you are told it cannot buntover because it has this or that component or configuration. The only true assurances can only be given after thorough flight testing by a professional. Even then, don't trust that your gyro cannot bunt!

<u>Misconception #9:</u> **"A PPO happens when the rotor drag goes to zero and the high prop thrustline pushes the nose over!"** This is an over-simplified depiction of a Power Push-Over that confuses the real issue. The term "Power Push-Over" actually confuses the issue and creates misconceptions of gyroplane configurations that might be more likely to PPO! This visualization is often used simply because the true physics of the issue might not be readily understood by the "non-engineer" masses! I believe it is important to a gyro pilot's safety to actually understand the real physics of what is going on, so that a pilot might not have over-confidences when those confidences might not be warranted.

Because of the popularity of this PPO description, many people have assumed that only a high thrustline gyro can bunt over. This is not true – any gyro can bunt! A PPO is a popular visualization description for one type of buntover, but it does not prescribe all types of buntovers! The buntover is not the result of a loss of **Rotor Drag**, it is from a reduction or loss of **Rotor Thrust**. (Rotor Thrust is a vector combination of both rotor drag and rotor lift) A buntover or PPO is not wholly the result of a mis-balance of prop thrust and rotor drag when rotor drag is lost. A buntover occurs when the RTV is forward of the CG (G-Load unstable) and the rotor THRUST is reducing rapidly. The reducing rotor thrust (from a down gust or a forward pitching spindle) causes the nose and spindle to pitch further nose-down. This further reduces the rotor thrust, and the cycle progresses rapidly until something really bad happens – buntover, precession stall or rotor strike!

So, the real issue with a PPO, or any form of a buntover, is whether the RTV is, or can be, forward of the CG under any flight condition or dynamic reaction of the airframe. The inference of this PPO misconception is that any "high prop thrustline" gyro is likely to PPO. A high propeller thrustline – that is not balanced by an appropriate HS balance in the propwash - WILL have the RTV forward of the CG (G-Load unstable), and can be susceptible to PPO. But, a properly designed "high prop thrustline" gyro, employing an effective HS to solidly hold the RTV aft of the CG in flight, and thereby avoid the underlying CG/RTV relationship that might otherwise make a buntover possible. On such a machine, where the CG is assured (by proper "balance" of prop thrust with the HS) to be forward of the RTV (G-Load stable), a change in Rotor Thrust causes the airframe (and therefore the rotor) to rotate in pitch so as to reduce the G-Load disturbance and return the G-Load to the normal 1 G – the definition of Static G-Load stability!

A properly designed HS on a slightly high prop thrustline configuration can “balance” both the prop thrustline moment and any airframe drag or lift moments (functions of airspeed) to avoid speed/power combinations or any transients of speed or power or wind from rotating the airframe so as to allow the RTV forward of the CG at any time – thereby actually removing the physical mechanism of ANY type of buntover!

The point is that this over-simple PPO misconception, intended for the technically less savvy, can invoke over-confidence in one gyro configuration while dismissing another configuration that might actually present a higher degree of buntover immunity!

Sidebar 1:

Following are a few other often misrepresented concepts. Because I feel that a pilot who truly understands and appreciates the technical factors in gyro flight will make better and safer gyro flight decisions, I would like to present some related concepts here that are often mis-stated or mis-represented:

- A PPO or buntover is the result of a STATICALLY UNstable gyro – usually, G-Load static instability. PPO is not a DYNAMIC instability issue; it is a STATIC instability issue! For a G-load statically unstable gyro, when a G load transient is encountered, the RTV forward of the CG causes the airframe to pitch worse in the worsening direction. The nose-down pitch rotation can diverge rapidly into a buntover. This is the divergence of a negative STATIC stability reaction. A STATICALLY stable gyro will be highly resistant to buntovers.
- PIO is a DYNAMIC stability issue – rapid natural oscillation rates of a gyro that are inadequately damped so that the pilot reactively exacerbates the DYNAMIC reaction. PIO is not a STATIC instability issue. During a PIO, before the actual buntover, the gyro is actually statically stable – pitch is oscillating (severely) around the statically stable condition. An adequately DYNAMICALY stable gyro will be highly resistant, if not totally immune to PIO.
- A dynamic PIO rapidly progresses to an amplitude where the gyro RTV/CG relationship becomes statically unstable - CG aft of the RTV. At this point, the dynamic oscillation stops and the static divergent forward rotation progresses to a buntover. In other words, dynamic instability is not what bunts it over; there can be no oscillation around a stable condition when that stable condition no longer exists. It is the statically unstable condition of that moment that diverges the nose-down rotation into a full buntover.

Sidebar 2:

Here is another perspective on PIO:

As described herin, PIO is most likely on an inadequately dynamically stable gyro – one that has a rapid natural, short-period oscillation rate with inadequate damping. If a gyro has a high natural oscillation rate, damping is absolutely required.

If a gyro does not have a “passive” dampener or stabilizer, the pilot must constantly be “actively” stabilizing the aircraft. With experience, this can eventually be automatic or subconscious pilot control inputs, but the pilot must always be "balancing" the gyro around a steady-state condition (airspeed, attitude, G-load, etc.) This is not unlike the constant work it takes to balance a yard stick upright in the palm of your hand – you can do it, and with practice it is not difficult, but it does require constant "work" by the "pilot." In other words, for a statically unstable gyro to fly with relative stability, the pilot must be the "active" stabilizer (a human autopilot!) – constantly working to maintain the steady condition.

In some ways it can be said that this entire gyro/pilot system is indeed statically stable, even though the gyro itself is not inherently statically stable by itself, and would diverge into extreme conditions if the pilot were not in the "active" stabilization "control loop." The pilot is the "stabilizer!" So, as in any STATICALLY stable condition, the gyro/pilot DYNAMIC stability becomes the issue – the gyro/pilot's reaction to a disturbance of wind or G-load or over-reactive pilot input. In the absence of any other "passive" stabilizer, it also falls on the pilot to provide "active" DYNAMIC damping! The experienced pilot can probably dampen slower rate disturbances or oscillations. But, the human pilot is just not able to react with proper timing or degree when rapid rate natural oscillations might occur.

So, PIO can be envisioned as a stabilizer (the pilot) that is adequate at the common slower rate oscillations or disturbances, but is inadequately designed to handle the more rapid oscillatory rates that are true and fatal PIO events. I suggest that the old argument that training or experience can recognize and correct PIO is simply not true. If a human is the only stabilizer on a machine that has a rapid natural oscillation rate, the human pilot is simply not adequate to stop such oscillations and will actually exacerbate the rapid rate oscillation amplitude – PIO. It may be true that an experienced pilot, with perhaps greater sensitivities to seat-of-the-pants indicators, may be less likely to venture into conditions (of speed or power or wind) - where gyro/pilot stability "feels" dangerously inadequate!

Try this fun experiment: Balance a yardstick (or meter stick) upright in the palm of your hand. Notice, with a little work, you can keep the stick upright. This might be the analog of a gyro pilot's work to "stabilize" the slow natural response tendencies of a gyro. Now, do the same thing with a shorter, 1-ft ruler. Notice the human "pilot" will have difficulty "stabilizing" this faster reacting, short-period, PIO-type instability. This somewhat characterizes what happens when the pilot "stabilizer" experiences a situation where the pilot skills are inadequate. Now, clip a weight to the top of each of these sticks, and repeat the exercise. Note that the higher Moment of Inertia (MOI) "gyro" becomes somewhat easier to "stabilize" – characterizing the differences between higher MOI and lower MOI gyros.

The point is it is much safer to rely on the installed "passive" stabilization that an adequately effective horizontal stabilizer can provide, and not trust solely in the pilot's abilities to totally provide "active" stabilization through all flight conditions. Someday, that flight condition of wind transient, speed or pilot reaction might exceed the capability of the "human stabilizer!" "Passive" stabilization also reduces or can completely remove the pilot attention and workload otherwise required to statically stabilize the gyro and constantly correct for disturbances. This means more fun with less work and a whole lot less anxiety!

Have a safe flight – Greg

GLOSSARY of GYROPLANE TERMS

The selected terms below are an excerpt from the complete Glossary of Gyroplane terms that can be found at http://www.magnigyro.com/gyroterms.pdf.

Bunt-Over:

A sudden uncontrolled forward tumble about the pitch axis in a gyro; unrecoverable fatal. A buntover is a self-sustaining divergent nose-down pitching motion, accelerated and propagated by rapidly changing or diminishing balancing moments on the airframe. Typically, when the nose-down pitch of the airframe and/or rotor disk reaches a certain point, the nose-down pitching self-perpetuates and accelerates (positive feedback) to result in a full forward tumble. "Power Push-Over is one form of a "Bunt-Over", but not necessarily the only form of a bunt-over. A "Bunt-Over" is not necessarily a Power Push-Over. Without adequate gyroplane configuration design, a bunt-over can be initiated by wind gust, pilot over-reaction, or sudden power changes. *See also "Power Push-Over" and "Power Torque-Over."*

Damping (Dampening, Dampen):

The effect of a component or configuration that tends to reduce the natural oscillations of an object or system and restore the system back to stable equilibrium. All physical systems can exhibit rotational dynamic oscillations, such as in pitching the nose up and down. Without damping in such systems, the oscillations will continue indefinitely. As applies to gyroplanes, damping may be affected by a horizontal stabilizer, the offset gimbal/trim spring configuration, the pilot, friction or even an autopilot system. *See also "Damping Moment."*

Horizontal Stabilizer – HS:

A horizontal flying surface placed on the tail of an aircraft to provide a stabilizing moment tending to keep the aircraft aligned in pitch with the relative wind upon disturbance. The HS adds dynamic stability in pitch in the form of more precision and reduced overshoot in control response. The Horizontal Stabilizer serves to dampen the natural oscillatory pitch tendencies of the aircraft. A horizontal stabilizer on an aircraft is normally arranged to provide a down force or negative lift to balance the CG forward of the lift vector so as to provide airspeed stability. A horizontal stabilizer on a gyro is normally rigged for the same purpose but is also arranged so that the down force on the tail maintains the VCG forward of the Rotor Thrust Vector for pitch stability. The effectiveness of the HS is a function of its size, its moment arm from the CG of the aircraft, its airfoil shape efficiency, and any enhancement from the effect of propwash immersion. A HS can be arranged to react to both Free Airflow and accelerated airflow from propwash. *See also "Damping," "Horizontal Tail Volume," Airspeed Stability," Vertical CG," "Rotor Thrust Vector," "Moment," "Stabilizer," "Embedded" and "Free Air."*

Inertia:

The property of a moving or stationary physical object (an object having mass) to remain in that motion or to remain stationary. The property of matter that causes it to resist any change of its motion in either direction or speed. Inertia is what a person has when they fly forward against a seat belt when their car comes to a sudden stop. Inertial energy is stored in the speed of an object, and must be exchanged or dissipated in order to change or stop the motion of that object. Heavier (more massive) objects have more inertia. *See also "Momentum."*

Instability:

The property of an (unstable) object or system that causes its motion or condition to diverge or oscillate once disturbed. An unstable object or system will not self-maintain equilibrium or selfrestore to equilibrium once disturbed. External stabilization is required to maintain equilibrium of an unstable object or system – i.e.: pilot skill, horizontal stabilizer, autopilot, etc. An example of instability is a ruler balanced on end – once disturbed from vertical balance, it starts to fall over at a faster and faster rate. External control and/or effort would be required maintain the ruler balanced on its end. *See also "Stability."*

Moment:

A term used to represent a "torque" on an object such as a gyroplane that tends to rotate the aircraft about an axis. A moment is the product of a force acting on an arm ("moment arm") and the length of the arm. A moment can be thought of as leverage applied to turn or twist an object. For instance, an offset propeller thrustline provides a force pushing on a "moment arm" equal to the offset of the propeller from the vertical CG of the aircraft – tending to cause the nose to pitch up or down. Moments can be said to "balance" when the total moments in one rotation direction equal the total moments in the opposite rotation direction – i.e.: a child's teeter-totter with a weight of 50 Lbs located 10 feet from the pivot and a weight of 100 Lbs located 5 feet from the pivot on the other side. Both moments equal 500 Ft-Lb, but in opposite or "balancing" directions. *See also "Moment Arm."*

Moment Arm:

The distance from the pivot point (usually from the CG) to the point at which a perpendicular force is applied. For instance, a mechanic pulling on a 1ft long wrench would be applying that force to a 1 ft moment arm. The total moment applied would be the product of that force and the 1 ft moment arm. *See also "Moment."*

Moment of Inertia – MOI:

The rotational inertia of an object such as a gyroplane, or spinning rotor, that tends to resist a change in that rotation – either slowing down or speeding up a spinning object or starting a rotationally stationary object to rotate or spin. The MOI of an object is calculated by multiplying each chunk of mass in an object, by the square of its distance from the CG of that object (its "moment arm"). A higher MOI tends to be more difficult to start rotating or to stop rotating. The MOI of the airframe and of the rotor are important factors in the natural oscillatory frequency of a gyroplane. *See also "Inertia."*

Negative Stability:

The condition of instability. The tendency of an object or system to diverge from or oscillate around an equilibrium condition. An object or system that has negative stability will not maintain equilibrium or return to equilibrium once disturbed. A good website is http://142.26.194.131/aerodynamics1/Stability/Page3.html *See also "Instability."*

Neutral Stability:

The condition exactly between negative stability and positive stability. An object or system has neutral stability when it tends to neither worsen or improve its movement after a disturbance. An example of neutral stability would be a ruler pivoting on the 6-inch central pivot – when disturbed it neither returns to vertical or falls completely over. *See also "Stability," Negative Stability," and "Positive Stability."*

Pitch Damping:

The action of a stabilizing component on an aircraft to prevent or reduce the natural pitch oscillations of the aircraft. Pitch damping can be accomplished on a gyroplane from proper application of a horizontal stabilizer, by the appropriate action of the pilot, or by an active stabilizing system such as an autopilot. *See also "Oscillation," Damping," "Pitch" and "Horizontal Stabilizer."*

Rotor Thrust Vector – RTV:

The vector representation of Rotor Thrust usually depicted as an arrow with a specified magnitude and direction. In a gyroplane, the RTV is represented to be an upward and slightly aft pointing arrow approximately parallel and in-line with the spin axis of the rotor. The Rotor Thrust Vector is the vector sum of the Rotor Lift Vector and the Rotor Drag Vector. A common error in describing or attempting to understand the moments and forces acting on a gyro is to confuse or intermingle the use of both Rotor Drag and Rotor Thrust – one or the other convention must be utilized consistently throughout an analysis. For instance, if Rotor Thrust (combined lift and drag) is the representation of rotor forces used, then additionally describing the affect of a loss of Rotor Drag would be "double-dipping" the Rotor Drag component. *See also "Vector," "Rotor Lift Vector" and "Rotor Drag Vector."*