

# THE MAGNI DIFFERENCE

By Greg Gremminger

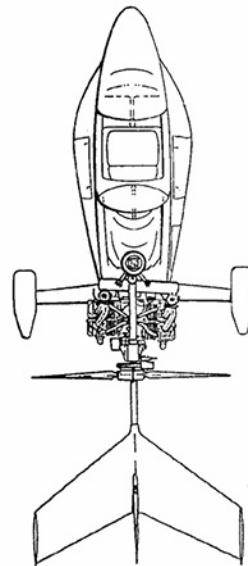
We are proud that Magni gyros have been a primary influence on the improved safety of our sport over the last couple decades. The safest and most popular gyroplanes around the world are either Magni gyros, or the number of aerodynamic clones of Magni gyros, that have essentially eliminated the traditional safety issues of Buntovers and Pilot Induced Oscillations. However, there are other less obvious, but still important, safety and reliability issues - other than simply the Magni "Big Tail Way Back" aerodynamic solution adopted by the Magni "clones."

Although the Magni "Big Tail Way Back" configuration is now popularly emulated by numbers of Magni "clones," some explanation of more hidden attributes of this configuration are worth discussing. The large horizontal stabilizer, mounted far back on the tail keel is an excellent way to afford "Dynamic Pitch Damping" to any aircraft. The big secret with the big tail is that the further aft it is mounted the much, much more effective it is as a DYNAMIC pitch damper. It turns out in gyros, as in all aircraft, the secret to positive, precise and stable control is the DYNAMIC damping afforded to the airframe by the horizontal stabilizer. This is the feature many gyro designers are now adopting - but there appears to be little appreciation or understanding of just how this is an advantage over just a purely large tail.

A large tail is a STATIC stability advantage certainly - most people understand this as a "balance beam" of the horizontal stabilizer statically balancing the destabilizing surfaces forward of the CG. This is all true in the simple determination of STATIC stability. But, as it turns out, strong DYNAMIC pitch damping is what even more so effects precise handling while also complementing or enhancing the aircraft's STATIC stability. In fact, strong DYNAMIC pitch damping can actually make a presumed statically unstable aircraft fly with strong static stability. This may seem implausible, and the technical reasons are difficult to understand, but there are numbers of examples that show this to be true.

A simple static analysis of the sum of moments is a very incomplete analysis of the stability and control performance of an aircraft. For instance, many designers, considering STATIC analysis only, strive for Centerline Propeller Thrustline (CLT), or Low Propeller ThrustLine (LTL) to achieve flight static pitch stability as determined by the sum of static forces acting about the Center of gravity (CG). Actually, a purely CLT gyro, or any aircraft, might not be statically stable anyway. A LTL configuration would actually be statically stable in a paper sum of moments static analysis - the CG would be forward of the Rotor Lift Vector (RTV) - but this would only be when the propeller is developing thrust to hold the CG forward of the RTV in flight. (When power/thrust is minimal, this LTL "Thrust Enhancement" of static stability is non-existent. When static flight stability depends on propeller thrust, the gyro is not necessarily statically stable or as statically stable, and the control handling may require more pilot proficiency in the less stable aircraft with power reduced.

True static flight pitch stability, independent of propeller thrust or even airspeed, can be provided by the horizontal stabilizer. The horizontal stabilizer can be mounted at a negative incidence angle to force the CG into its statically stable location forward of the RTV. This is one way to balance other static destabilizing airframe moments, such as a high Propeller Thrustline (HTL). But, the down-loaded



horizontal stabilizer requires more rotor (or wing) lift to compensate – requiring more power for flight with the down-loaded horizontal stabilizer – less efficient flight. This effect is minimized when the horizontal stabilizer is mounted on a long tail boom – more nose-up airframe moment with less down-load from the stabilizer.

The Magni secret, and the one copied by the Magni “clones,” is that the horizontal stabilizer is not counted on to provide a static stabilizing nose-up moment on the airframe. The horizontal stabilizer on the Magni, and on its “clones,” is absolutely level to the airstream (when properly loaded). This does not provide even enough nose-up moment to balance the HTL statically destabilizing moment from the high mounted engine on this configuration. The large horizontal stabilizer, mounted far aft of the CG, provides very strong DYNAMIC pitch damping to the airframe that effectively provides the necessary and strong static flight stability of this configuration. The Magni (and “clones”) “Big Tail Way Back” provides the DYNAMIC pitch damping that makes the gyro fly STATICALLY pitch stable – even though a simple Sum of Static Moments analysis would suggest otherwise. As it turns out, the “Way Back” part of “Big Tail Way Back” is the most important part towards the desirable strong DYNAMIC pitch damping.

Numerous examples of HTL gyroplanes, that some would suggest are susceptible to buntovers and pilot induced oscillations, are the new generation of gyroplanes that incorporate the “Big Tail Way Back” configuration. Magni gyros and its “clones” are perfect examples of this. This configuration is very certainly significantly HTL. Conventional “wisdom,” predominate in the gyro culture, suggests that these would be an accident waiting to happen – that they would be STATICALLY unstable and would therefore be very difficult to fly safely. However, these “Big Tail Way Back” configurations are shown by standard accepted static stability flight testing methods to be strongly statically pitch stable. Upon a disturbance from pitch attitude or airspeed, the aircraft inherently quickly returns to the original trimmed condition without oscillation or over-shoot, and without pilot input (both with the stick free and the stick fixed). This is STATIC flight pitch stability. The strong DYNAMIC pitch damping causes this aircraft to return to its initial static trimmed condition with minimal oscillations – actually no oscillations – that might induce pilot over control (Pilot Induced Oscillations).

Besides professional British Section T and other flight tests demonstrating the static pitch stability of this configuration, deployed experience with large numbers of Magni gyros and its “clones” demonstrate no tendencies toward buntovers and Pilot Induced Oscillations – the characteristics a purely but incomplete static sum of moments analysis might suggest. There are no reported incidences of Pilot Induced Oscillations or Power Push-Overs or buntovers in these “Big Tail Way Back” gyroplane configurations. Even more anecdotal evidence of the stable and precise control afforded by the strong DYNAMIC damping is the turbulence penetration and apparent safety of this configuration reported by experienced and less experienced gyro pilots in strong winds. More anecdotal evidence of these benefits come from the ease of learning to fly such configuration gyroplanes. There is none of the traditional “jab and counter jab” technique required on the traditional unstable gyrocopters of the past – control is precise and accurate – move the cyclic stick and the gyro obediently flies to that attitude with no oscillations or over-shoot that less stable gyrocopters might require. The aircraft controls exactly like all airplanes are intended to – except that it is much less susceptible to turbulence disturbances and still has all the beneficial attributes of a gyroplane (no stall, slow and fast flight, short and slow landings, etc.)

One last point before moving on to some real Magni Differences: This “Big Tail Way Back” dynamic damping benefit is not confined to only the low seater Magni and “clone” configuration. That applies to almost any configuration gyro that has a “Big Tail Way Back”. The point is though, with the incorporation of a strong dynamic damping “Big Tail Way Back”, it is no longer necessary to try to provide static stability with a cabin mounted very high above the ground to achieve CLT or LTL. Gyro

configurations that depend on propeller thrust to enhance static stability do not assure static stability and familiar/safe handling in all flight situations. When power is reduced or quits, the stability enhancement disappears. But, more importantly at higher airspeeds where gyros without good dynamic damping surfaces become less stable, the prop thrust reduces naturally at higher airspeeds – just where the enhanced static stability is most necessary! Using a “Big Tail Way Back” for strong dynamic pitch damping, that effect and Static stability actually improves at higher airspeeds.

We are certainly very proud that several decades of Magni safe operation has influenced the gyroplane community and designers to incorporate such an important technology as a “Big Tail Way Back.” Actually, that has never been a secret that Magni demonstrates. The Autogyros of the 20’s and 30’s did the same thing with their tractor configurations and long tails. And, almost all airplanes, from Curtiss and Bleriot, to today, employ the “Tail Way Back” configuration to achieve the control characteristics that have proven to be so desirable and safe.

Having said all of the above, I now want to expose to you some Magni differences that the “clones” have not fully appreciated or successfully emulated.

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- **The Magni Rotor:**

**Precision, composite rotor blades:**

The Magni rotor and rotor system is very unique. It is fabricated under precise procedures and autoclave processes from high-tech composite materials – carbon fiber and fiberglass. The precision of this process controls very exacting geometric and mass distribution consistency for superior balance. The “balance” of any rotor system requires the aerodynamic axis of lift to be coincident with the mass axis and the exact spinning axis of the rotor. Most rotor systems using extruded and/or fabricated components have difficulty in exactly matching these two centers exactly, with rotor balance being a compromise between the two. The precise control of the fabrication of each Magni rotor blade, where each station of the rotor from root to tip is an exact reflection of that station on the opposite rotor, precisely aligns all three axes for unsurpassed rotor smoothness. Unlike other composite gyroplane rotor blades, Magni does not mix an aluminum spar with composite materials – the process of curing the composite materials in an autoclave causes geometric distortions and a minimum, due to the mismatched coefficients of expansion of the two materials under heat. By using a carbon fiber spar the full length of the rotor blade, the autoclave process yields precise geometry and mass distribution on each rotor blade. Magni gyros have been renowned for the smoothness of their rotor system.

**High inertia rotor:**

Magni’s composite rotor blades are indeed heavy – about twice as heavy as most other blades of similar size. Some would tout this as a disadvantage to high maneuverability, but the high inertia of a heavy rotor provides very forgiving flight and significant control and stability advantages. Traditional gyrocopters had very light stick forces – could hardly feel when you were moving the stick. Many in the gyro community consider this light stick characteristic to be a sporty advantage and why gyros are so highly maneuverable. What is not so popularly admitted is that this lack of sensation of stick pressure and stick movement has actually contributed to the traditional bunt over and/or Pilot Induced Oscillations that are so famously attributed to traditional gyros! Because of the sensitive nature of cyclic rotorcraft control, very slight unfelt movements of the stick can result in rapid and surprising maneuvering – often inadvertent and unintentional from startled novice pilot reactions. Pilots of all aircraft fly by the feel of stick or yoke pressure in their hand and arm, not by the less precisely sensed actual movement of their hand or arm. When stick feedback pressures cannot be readily felt by the pilot’s hand or arm, the tendency for over-control is possible because, without this stick feel, the pilot needs to wait for a reaction in the attitude of the airframe or a corresponding feel of G-Load in their “seat of the pants”. In fact, proficient pilots

subconsciously learn to gage their proper and precise control input with the consistency of the feel of the stick and the corresponding seat of the pants G-Load sensations in their seat, back, shoulders and neck. It is this consistency between the feel of the stick and the feel of their “seat” that makes proficient pilots able to fly with precision, and/or to recognize a mismatch in these two sensations. A subconsciously detected mismatch would indicate entering into an uncomfortable realm of instability where stick pressures are not timed with or proportional to the pilot’s “seat of the pants” G-meter. For this reason, Magni gyros intentionally provide strong stick “feedback” feel to help especially new pilots avoid any tendencies to over control and possibly initiate Pilot Induced Oscillations. When a pilot has little feel of the resistant pressure in the cyclic stick, as seems to be desired by many for “light touch” maneuverability, there is also the tendency for less proficient pilots to over control. Lately, there seems to be recognition among more in the gyro community that higher inertia blades actually provide this safety advantage. The option of tip weights in some of the lighter aluminum rotor blades is becoming more popular. Most describe this as “more forgiving”. As far as a maneuverability disadvantage of a heavier rotor and stronger stick forces, the rotor still responds to commanded cyclic displacement inputs and will still maneuver just as much and quickly as any similar weight gyro – just need to use a little muscle to make more severe maneuvers while the heavier stick reminds you that you are making them.

Magni’s higher inertia rotor presents another stability advantage. As discussed above, DYNAMIC pitch damping is an advantage to stability, avoiding bunover and Pilot Induced Oscillations, turbulence reaction, etc. Above we were talking about AIRFRAME dynamic pitch damping. But the spinning ROTOR also has its own independent DYNAMIC pitch (and roll) damping properties. These properties are a function of the rotor RPM, and of the inertia of the rotor. Now, the airframe and the rotor are independent inertial DYNAMIC systems. But, they are both interacting with each other – the rotor interacts with the airframe pitch through the Rotor Lift Vector lifting or lowering the nose, and the airframe interacts with the rotor through cyclic inputs of the rotor spindle which tilts with the

airframe whenever the airframe pitches or rolls. Any two dynamic inertial systems that can mutually affect each other can either excite or dampen harmonic reactions in the whole system. When the two natural response rates or natural oscillation frequencies interact they can create desirable or undesirable harmonies as a total system. Picture a child swinging their legs on a long swing. When his legs are swinging in phase and synchrony with the swings of the swing, the swing oscillations grow. When their legs are swinging in the opposing phase with the swing, the oscillations dampen – can be slowed down to a stop. When the child swings their legs out of synchrony with the natural swinging oscillations of the swing, very erratic movements of the swinging swing are generated. Now picture this whole swing system with a child on a very short swing. More difficult to harmonize leg swings with swing swings! This is analogous to a rotor system that either matches or harmonizes with the natural rates and frequency of the airframe, or not. The heavier Magni rotor is designed to match or harmonize with the airframe dynamic reactions to produce a total harmonized response to pilot input and/or turbulence disturbances. A heavier rotor already has an inherent advantage in damping turbulence disturbances simply because of its higher inertia. But, a rotor system that is dynamically harmonized properly with the airframe, as the heavier Magni rotor is, makes the whole aircraft control and responses much more desirable and intuitive. This is often recognized by pilots who fly various brands and models of gyros – the Magni is more comfortable flying in heavy turbulence. The higher inertia rotor matched dynamically with the airframe is the reason. In short, there are other issues to consider when choosing a rotor to install on a gyroplane, or any rotorcraft, other than it is simply light or cheap. Magni has done the development work to evolve this desirable harmony between the two systems.

#### Rotorhead configuration:

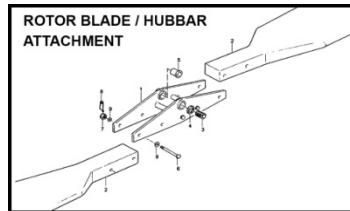
The Magni rotor system as a whole is very unique in the gyro world. Examine the pictures below. There are no similar rotorhead configurations to the Magni configuration. Most rotorhead configurations are variations on the Bensen rotorhead. The Magni rotorhead does not use the rather thin “teeter towers”

that can flex sideways with loads on the rotor. Magni uses a solid “teeter block” that includes the internal large main double ball bearings. The block cannot flex in any direction. Flexure of “teeter towers”, especially on heavier 2-place gyros where taller “towers” are necessary, creates 2-per-rev rotor shake.



The Magni hubbar uses two thick welded steel plates that straddle the teeter block. The rotor blades bolt sandwiched between the two hubbar side plates with large horizontal bolts. There are no provisions for adjusting either the blade pitch or the “string” alignment of the two rotors. The blade pitch and “string” are controlled by the very precise fabrication of the rotor blades that provide for very exacting blade aerodynamic and weight symmetry between the two blades. The traditional rotor head and hubbar configuration requires adjustments of both blade pitch and blade “string”. (“Stringing” gets its name from the process of stretching a string from one blade tip to the other to adjust the alignment of the blade attachment to the hubbar so that the stretched string centers over the top of the hub bar. The idea is to tighten the attachment bolts with the two blades aligned geometrically exactly 180 degrees across from each other.) These adjustments are necessary in less precisely fabricated rotors in order to find the best compromise between the rotor center of mass and its aerodynamic center – and its spindle spinning axis. The common rotor head and hubbar configurations attach the blades to the hubbar with a series of smaller vertical bolts that allow some lateral adjustment in the bolt hole tolerances to make the “string” adjustment. Traditional rotor configurations allow for a method also to adjust or shim the pitch of the blades relative to each other – to compensate for aerodynamic imbalances between the two blades. (The disappointing thing about this whole process is that the stretched “string” may identify the geometric center to the two blades. But, with less precise blade construction or fabrication, this does not assure that

either the mass center or the aerodynamic center will be aligned with the spinning axis of the spindle. Such adjustments on most rotors are a compromise of all these centers – some rotors can be made smoother, and some just cannot because of varying imprecision of the rotor blade mass distribution and blade/airfoil geometry.)



Magni composite rotor blades are fabricated with such precision that these “string” and blade pitch adjustments are not necessary. Each blade is then precisely matched to its partner based on very precise measurements. The absence of such adjustments assures the alignment cannot change while also assuring consistent re-assembly without time-consuming “stringing” of the blades. The two horizontal bolt attachments of the blades to the hubbar assure consistent “string” and blade pitch repeatability.

#### **Rotorhead teeter bearings:**

Few gyroplane rotor systems, in the interest of lower costs, use actual bearings for teeter bearings. Some may use roller or pin radial bearings for the teetering action, but others simply use brass and steel sleeve bearings. To minimize teeter 2-per-rev rotor shake, friction in the teeter action must be as low as possible. Sleeve bearings can get dirty or even gall over time – adding friction that shows up in rotor shake. Another consideration in the teeter bearing is to minimize any ability of the rotor hubbar to slide sideways on the teeter bolt. Most gyro rotor systems specify plastic shims that may allow as much as .010 inch side play of the rotor – this is what Igor Bensen allowed in his original Gyrocopter. Any side to side play on the teeter bolt adds another strong significant source of 2-per-rev rotor shake.

Magni rotor heads use compound bearings for teeter bearings – mounted in the solid “teeter block”. These

compound bearings have both radial and axial roller bearing surfaces. With both radial and axial bearings, the Magni teeter bolt arrangement allows ALL axial play to be removed – to eliminate that source of 2-per-rev rotor shake. The Magni teeter bolt configuration also provides side-to-side (chord wise) adjustment of the rotor on the teeter block – to easily fine tune any remaining chord imbalance of the rotor. (Some other quality rotors do also provide for precise chord wise adjustments, but most simply require adjusting shim thicknesses to fine tune chord balance.) For many rotors, these adjustments are very necessary, and time consuming to do, in order to find a less than perfect compromise for the inherent rotor blade mass, geometric and aerodynamic imprecision.

#### **Rotor life:**

The fatigue life of rotors is a common consideration for all rotorcraft. While some of the simpler single-seat gyros do not actually rack up long operational lifetimes, many of the current crop of new generation gyroplanes require significant investment and should be expected, with reasonable care and regular maintenance, to last for many years and hours of enjoyment. Unfortunately, there are questionable lifetimes for several popular rotor systems on the market today. The questions have arisen when operators in recent years have found fatigue cracks in aluminum hubbars and blade attachment areas on relatively low operational hour gyros. Some producers have necessarily required close frequent inspections and relatively low-time mandatory replacement of rotor blades and other rotor components. Just the known history of such issues, to me, makes flying with those components a bit stressful.

The Magni composite rotors avoid the traditional fatigue life issues of many rotors. There are Magni rotor blade assemblies that have flown in excess of 3000 hours – most of those in rugged training hours with students. There have never been any reported rotor failures or even structural cracks with Magni rotors – other than obvious rotor strikes with hard objects. (Most Magni composite rotor damage, deep gouges and other impact damage, are easily repaired.) Barring an actual crash, most damage is usually cosmetic only. Magni does now however, require

replacement of rotor blades at 2500 operational hours. This is mostly so that the factory can evaluate such high time rotors to see if there are any issues developing, and to eventually determine if the 2500 lifetime limit can be extended. 2500 hours is exceptional for rotor life on any rotorcraft, and certainly much better than some rotors which are life limited at even less than 1000 hours!

Full composite material construction is a major reason for the long trouble free life of Magni rotor blades. But the Magni hubbar attachment with large lateral bolts, rather than vertical bolting, avoids top side and bottom side stressor points at the bolt holes and hubbar tips that would focus the fatigue stress at those most critically stressed root attachment points. With the high stress concentration points unavoidable with common vertical attachment bolts and holes, extruded spars and even full extrusions may be prone to stress fatigue cracks at or near these stressor points – often difficult to observe internally. Magni simply avoids all of these issues with use of a full carbon fiber spar and fiberglass construction. The Magni rotor spar consists of a large number of unidirectional carbon fiber strips, routed tip to root through a rounded window in a massive aluminum attachment hub block at the root of each blade. The horizontal configuration attachment bolts – two very large bolts that sandwich the aluminum attachment hub between the hubbar steel plates – avoid the stressor points created by vertical bolts holes and the tip of the hubbar on standard configuration rotors. As far as we know, Magni is the only producer that uses this entire rotor and hubbar configuration. As far as we know, there have been no normal use failures of Magni rotors or hubbars in the 20-30 years that this design has been in operation. Even a popular fiberglass rotor blade that employed an aluminum spar and standard vertical blade attachment bolts had severely limited life and experienced numerous cracking issues. If there is one issue that really takes the fun out of flying, it is probably having doubts about the structure and reliability of the rotor!

#### **• Ground Stability:**

We all tend to focus on the flight stability of gyros. Flight instability events such as buntovers or Pilot

Induced Oscillations have been the traditional headline safety and fatal accident issues with gyros. With the advent of the “Big Tail Way Back” configuration, those stability issues are really a thing of the past for gyros that employ that concept. However, not all accidents are related to just FLIGHT stability. It is important also to have strong ground directional stability in order to avoid dangerous and damaging accidents upon takeoff or landing. Unfortunately, ground roll-overs are still occurring, even with some “new generation” gyroplanes. Ground roll-overs cause severe damage but can also cause severe occupant injuries – including death! It is a bit disappointing that some Magni “clones” have copied the important parameter of dynamic flight pitch damping, but fail to recognize the importance of ground directional stability also built into the Magni gyros.

Like all tricycle gear airplanes, Magni employs a strongly castering nose wheel. All pusher gyroplanes land and takeoff as “tricycle” landing gear aircraft. The advantage of tricycle aircraft is that they tend to straighten out automatically when the nose wheel is touched to the ground – either on takeoff or upon landing. For a tricycle landing gear to function properly though, the nose wheel must be able to caster – freely align itself with the direction of motion of the aircraft. For example, especially when landing with a crosswind, or during full power takeoff acceleration, the necessary cross-control rudder deflection may align the (rudder pedal coupled) nose wheel in a different direction than the direction of movement of the aircraft. If the nose wheel is unable to freely align with the direction of aircraft motion, the deflected nose wheel will “dart” the nose to one side when it touches to the ground. Even low center of gravity gyros, such as the Magni “clones” can easily roll over when the nose is suddenly deflected away from the direction of motion. This sudden nose “dart” may often excite the pilot into control reactions that exacerbate the problem.

Many gyros, for reasons I have yet to understand, use a nose wheel without any caster. Picture the castering wheels on a grocery cart! The touch point of the wheel to the ground surface must be behind the vertical steering pivot axis of rotation of the nose wheel strut. To work properly, the angle of the nose wheel strut

must be closely vertical or perpendicular to the ground – picture the grocery cart again! To make matters worse, many gyros actually cant or angle the nose wheel strut severely forward. This probably looks good, but further prevents the nose wheel from straightening out when touched to the ground. Actually, when weight is applied on the nose wheel, as upon landing, a cant forward can cause the nose wheel to deflect away even further! Some producers even recognize this issue and require in their training and flight manuals to hold the nose wheel off the ground until the gyro is well slowed down or almost stopped. (I actually sold one of the first USA Magni gyros to a customer who had recently rolled over his other-brand expensive gyro for exactly this reason!)

The potential for ground roll-over upon a nasty sideways or drifting touchdown is one concern here. But, the restriction to not touch the nose wheel at higher speeds on the ground actually limits some of the operational and performance benefits of a gyro. For instance, the standard FAA short field takeoff procedure for gyros (similarly for most airplanes), and for the Magni gyro, is to lower and hold the nose to the ground once the rotor RPM is adequate to lift the nose off the ground, hold the cyclic well forward to reduce the rotor disk Angle of Attack and minimize rotor drag, allow the gyro to quickly accelerate to best rate of climb airspeed in a shorter ground roll, and then rotate and climb immediately at the best angle of climb airspeed,  $V_x$ , when it is reached on the ground. This procedure shortens the rolling distance on the ground by minimizing rotor drag after takeoff. Rotor RPM is reached, and avoids the need to fly some distance in ground effect to build airspeed to  $V_x$  for best angle of climb after liftoff. When the nose wheel cannot be re-touched to the ground at the higher airspeeds – on takeoff especially when full power actually requires more rudder deflection – the rotor disk cannot be leveled to minimize drag and lift, ground roll is longer, acceleration limiting rotor drag is more, and rotor lift initiates a takeoff at airspeed well below  $V_x$ .

The strong caster of the Magni nose wheel avoids the potential for a “nose dart” that could cause a narrow wheel base gyro to roll over; and allows full application of short field takeoff procedures in even strong

crosswinds. In my over 3000 hours of flight instruction provided in our Magni gyros, I have experienced some very severe sideways or drifting landings with students. We often train even new students in hefty crosswinds. Sometimes the ground stabilizing reaction of the castering nose wheel straightening out the aircraft can be startling to the student, but we have never had a roll-over tendency with any student. Students often make multiple landings in a single landing attempt, often exciting rudder control reactions that could exacerbate the situation – and still no real roll-over tendencies. The point is, ground stability issues might not be the cause of such severe and fatal accidents as flight instability has been in the past, but ground roll-overs are still serious and dangerous. Magni gyros address all types of stability – including ground stability.

- **Prerotator utility/safety/reliability:**

Strong prerotators are a necessity on the new generation 2-place gyros that are increasingly popular today. Prerotators come in a multitude of designs and configurations. Hydraulic prerotators are intuitively popular, but without very heavy large diameter hydraulic lines and large motor/pumps, prerotation without wind help can rarely exceed about 150 rotor RPM. Electric prerotators are also intuitively attractive, but they require large batteries and some sort of “soft” actuation to avoid sudden damaging motor start torques applied to the rotor and mast and prerotator gear. Electric prerotators are often good for only one pre-rotation before requiring re-charge of the battery on the ground or with an hour or so of flight – one good prerotation at a time!

Mechanical coupling from the engine to the rotor is the most popular configuration. There are two prominent types of mechanical coupled prerotator systems. Historically, the “flex cable” type prerotator has had the most success and use. The commercial versions of the “flex cable” prerotator systems were developed mostly for lighter single place gyros with lighter rotors. The “flex cable” itself is the limiting factor for both the size of the rotor and the top speed of prerotation due to the higher torque stresses required through the flex cable.

For larger rotors on some new generation gyroplanes, some designers have reverted to straight torque shaft drives, employing right angle gears and a “U”-joint coupling at the rotorhead. Intuitively, such a system can be designed to handle very high prerotator torque applications. However, good intuitive ideas do not always resolve all problems. Such systems that use a “U”-joint at the rotorhead, to allow pitch and roll movement of the rotorhead, create limitations on how the system may be used. To prerotate with a “U”-joint at the rotorhead, the rotorhead (and rotor) must essentially be held in a level condition – keeping the “U”-joint essentially aligned straight with its driving shaft. Otherwise damaging stresses can be applied to the “U”-joint when the shafts are rotating – prerotator is engaged to the engine.

For such shaft drive / “U”-joint systems, the rotor cannot be pitched or rolled from level during prerotation – must be held level with forward and centered cyclic stick. That means it is difficult to taxi with the prerotator engaged. That means that any wind or wind from forward movement cannot be utilized while the prerotator is engaged – can’t tilt the rotor back to catch some prerotation helpful wind – such as on initial roll to shorten the takeoff roll. That also means the pilot essentially must roll onto and align with the runway before starting prerotation. The ability to prerotate before crossing the hold short line before entering an active runway, the ability to allow forward movement wind to help accelerate the rotor RPM during roll onto the runway, the ability to have takeoff ready rotor RPM as soon as you are aligned on the runway, is difficult or impossible with such shaft drive / “U”-joint prerotator systems. On busy runways, especially if/when a controller asks you to expedite or trying to fit into runway traffic, you do not want to have to stop on the runway and only start prerotation at that point, with your back toward oncoming traffic.

The ability to achieve a higher prerotation rotor RPM shortens the takeoff roll. But with a prerotator system that must be held forward until the prerotator is disengaged, the higher prerotation rotor RPM must be achieved solely with engine power – cannot tilt the rotor aft to collect some helpful wind for prerotation. That means that the rotor can only be tilted back for

building rotor RPM to takeoff RPM after the prerotator is disengaged – when roll is first initiated. With all of the mechanical restrictions, it can also be difficult or damaging to have to re-engage the prerotator if ever needed when the rotor might have slowed down below a safe RPM to begin acceleration down the runway. All of this easily leads to the opportunity to “flap” the rotor – outrun the rotor RPM because the rotor RPM is below, or allowed to dissipate below a safe speed for the takeoff full power acceleration.

Some prerotation systems employ a “push button” prerotator engagement system. These systems are intended to automatically engage the prerotator clutch at a rate that engages the Bendix mechanism at the rotor head, but avoids excessive torque on the system before the rotor RPM builds. These systems can make it difficult or impossible to re-engage the prerotator until the rotor is slowed to a stop – not necessarily safe to do on a busy runway with possible traffic behind you.

The Magni rotor system employs a large diameter flex cable to handle the higher power of the larger rotor and higher prerotation rotor RPM. The flex cable allows full cyclic control range of the rotorhead during all phases of prerotation and taxi. This allows prerotation to full available prerotation RPM before or during taxi into position on the runway. When done right, and using the wind through the tilted back rotor during this taxi, the gyroplane is ready for immediate takeoff acceleration as soon as it is aligned on the runway – no stopping and worrying about traffic behind you while you prerotate! No prerotation techniques and procedures, or third hand required buttons to push, after you are on the runway! The Magni prerotator system allows prerotator engaged initial takeoff roll, with the rotor tilted back to use the wind to build rotor RPM quicker and higher. Prerotator engagement is applied by the pilot with a lever that allows re-engagement of the prerotator at any point or RPM, while also allowing the pilot to build rotor RPM as aggressively as needed.

The Magni prerotator system is very robust and capable of no-wind prerotation rotor RPM up to around 300 RPM. (Normal takeoff prerotator RPM is 220 RPM. This RPM allows for immediate safe

application of full power, full aft stick acceleration down the runway. Higher prerotation RPMs are available for Short or Soft Field takeoff procedures.) The Magni prerotator system is designed to be a robust and reliable system, with considerations of maximum takeoff performance, assured prerotation to avoid possible blade “flapping” on takeoff roll, and without complicating procedures and mechanics that can lead to damaged parts in a hurried or stressful situation.

- **4130 steel airframe:**

Traditionally, gyros have been constructed with bolted and gusseted aluminum airframes. For more durable and long-lasting reliability, and with a century of experience in the processes, 4130 “Chromoly” (Chrome-Moly) steel structures have been refined and adopted as a primary structure technology for the entire aerospace industry. Lately some gyroplane manufacturers have begun using welded stainless steel as the primary structure in order to try to save weight and cost above standard aircraft steel technology.

Magni may be the only major manufacturer that has applied aircraft standard 4130 “Chromoly” steel and associated aerospace industry standards to its primary gyroplane airframe structure. Magni steel airframes are professionally welded with varying tube wall thicknesses engineered to address distributed strength and fatigue stress requirements while minimizing total weight. Stainless steel has a low specific gravity (low weight per unit volume) and may be less expensive than 4130 Chromoly. But, Magni, and most in the aerospace industry, consider stainless steel to be unacceptable for airframe structures because of its much lower resistance to fatigue cracking, difficulties in specialized welding and weld stress relief processes, and need for thicker tube walls (defeats perceived advantage in total weight) to offset its strength and fatigue deficiencies. So far, gyroplane industry experience with stainless steel airframes has incurred structural fatigue cracking in critical areas (the mast!!). Additional welded components have been added to address cracking in specific high stress areas, but typically such remedies simply transfer the high stresses to new areas.

4130 “Chromoly” steel is an alloy steel, containing Chromium and Molybdenum that is widely used in the aerospace industry because of its superior strength and fatigue and corrosion resistance. Chromium increases the hardness, elastic limit, tensile strength, and resistance to corrosion and wear while reducing thermal conductivity – a welding process advantage. The Molybdenum further increases the strength and the hardness and improves the response of the metal to the various treatments post-welding processes. The steel Magni uses is professionally “normalized”, an aerospace standard treatment that improves the grain of the steel returning it to its original condition after being worked. This leads to an improvement in the strength and performance of the welds. Such normalization is difficult and less proven with welded stainless steel.

4130 Chromoly has much greater strength in both compression and tension, and with a lower specific gravity than other steels, including stainless steels. The 4130 alloy steel Magni uses is the aeronautical steel par excellence. It is particularly strong (many other steels, including stainless steels, crack and break well before the 4130 even bends!) and is more corrosion resistant than even many of the stainless steels.

Magni uses 4130 steel for the complete airframe structure, all rotor head components, all control linkage, and all metal parts that have any structural importance. While we appreciate experimentation with new materials and structural innovations, Magni does not consider stainless steel airframe technology to be properly matured and appropriate for production aircraft structures. The truth be told, with proper engineering, 4130 Chromoly steel still achieves superior strength per weight performance over all other materials - with mature and decades proven superior resistance to fatigue cracking and corrosion. With proper engineering, 4130 Chromoly steel still far exceeds the presumed weight advantage of lighter steels and even aluminum – which may anecdotally be demonstrated with the necessity of additional airframe structural components added to later evolutions of gyros constructed with these less proven materials. And the fact that those manufacturers specify relatively short life limits on AIRFRAMES and critical

ROTOR COMPONENTS suggests that perhaps even those producers feel those technologies are not quite ready for prime time use in aircraft. In particular, fatigue strength is critical in rotorcraft. Magni 4130 airframes have no life limits. Magni has experience with airframes that have over 3000 rugged student training hours, even operating on more rugged turf runways throughout the world. As with rotors, doubts about structural reliability, especially concerns with - often hidden - fatigue cracks in more brittle materials, can really take the fun out of flying. Here again, the old adage, “you get what you pay for”, is more than appropriate.

- **Turbulence penetration/stability:**

Above we discussed the flight stability benefits of the “Big Tail Way Back” airframe dynamic damping configuration. That basically eliminates the potential for the flight instability issues of buntovers and Pilot Induced Oscillations. However, there is more to the story of strong dynamic damping and its benefits. The autorotating rotor also has inertia and presents dynamic pitch (and roll) damping into the whole system. As we mentioned, Magni rotor inertia and dynamic response is tuned to the airframe dynamic response so as to harmonize controls and turbulence reactions. This is achieved with the heavier, higher inertia Magni composite rotors. The harmonized rotor system contributes and amplifies not only flight stability, but improves the whole system’s ability to penetrate and dampen wind gusts. The result is a smoother ride through strong turbulence without requirement for pilot corrective actions. With heavier rotors, the gyroplane is able to penetrate turbulence more comfortably.

No other gyroplane employs such high inertia rotors. Although the reports are anecdotal, pilots who are familiar with flying both Magni gyros and other models in turbulent conditions, such as around mountains and hot thermally deserts, report the Magni is much more comfortable in turbulent conditions. I have an anecdotal report to this myself. In preparing for four Magni gyros to make a cross-country trip from Missouri to California this past Summer, I inquired with another experienced gyro pilot who happened to

fly across the same hot Southwest U.S. desert a few years ago in a Magni “clone” – “Big Tail Way Back” - but with a lighter aluminum rotor. His advice to me was to fly in the mornings only because the thermals are too rough in the heat of the day in the desert. The four of us did fly, four Magni M16s, full days across New Mexico, Arizona and Nevada in the heat of 110 degree days. Although we could tell it was indeed turbulent, none of us were deterred from continued flying from morning to dusk in these conditions. On that same adventure, in the high and rough country just west of Albuquerque, a storm wall cloud chased us on a retreat back to an alternate airport. For a good 20-30 miles, we were in the grip of that gust front, with cold air and strong winds undulating against rugged terrain. If I had had my druthers, I would have avoided that experience, adrenalin was pumping! But all of us out raced that storm to take refuge in a lonely airport providing shelter from the immediate storm!

- **Limited takeoff rotation attitude:**

This may seem like a little thing, or an excuse for limited rotation angle on takeoff and landing. But, Some Magni “clones” have raised tails, presumably to be able to rotate to higher angles of attack on both takeoff and on landings. The intuitive and promoted advantage of being able to raise the nose further in a landing or takeoff stance is slower takeoffs and landings. But, some pilots have discovered that it takes proficient skills to apply this technique without getting into trouble. The ability to rotate too quickly to a high angle of attack can cause the gyro to jump out of ground effect losing airspeed and dropping back to the ground in a rough, nose high attitude. This has happened – with the associated roll-over!

Magni gyros do not have raised tail booms, limiting the rotation angle on takeoff to an angle that prevents extreme jumps off the ground to get into this trouble.

Promoters of these high raised tail configurations also boast that they can land at slower airspeeds – higher disk angles of attack because they can touch down with a higher nose attitude. This is certainly true – can touch down at lower airspeeds and stop a bit shorter, maybe. But, that landing attitude also invites the

ability for the rotor to strike the ground if the landing attitude is too severe. This has happened! Magni gyros do not encourage such tail low landings, but if you were to land on the tail wheel first, the tail forces the nose lower to avoid rotor strikes – maybe a bit rougher landing, but all the parts are still together!

Another reason that some gyro configurations have high tails is so that the horizontal stabilizer is in the propwash – to amplify the stability contribution of the horizontal stabilizer – when the prop is producing propwash. The propwash can have a nearly two to one effect on the power of the horizontal stabilizer. Actually, this is not necessary for Big Tails Way Back because they already have a strong leverage arm for dynamic damping effectiveness. With this horizontal stabilizer in the propwash arrangement, changes in power level can change the stability/handling characteristics of the whole machine between power on (best), and power off (not as much). Professional aircraft designers prefer that the control and handling properties, sensitivity to controls, does not change for any reason such as an abrupt power change. This is not such an issue for pilots experienced in this characteristic, but it can be an issue for more novice pilots expecting to penetrate wind gusts, for instance, with power off as well as they experienced with power on.

Magni may have the most extensive experience of gyroplane developers in these subtle variations and configuration issues. Over the years they have actually progressed through 24 (latest is the M24) configurations (many of these being non-production prototype configurations to test various concepts). The production flock of Magni gyros today take advantage of these years of prototype and testing experience and Magni Gyro has only released configurations to the public upon extensive evolution to those production configurations. Discouragingly, some designers have simply taken an intuitive concept, applied it to an obvious beneficial configuration (Magni “clones”), and released production models without such extensive evolution and iteration with prototype models. In my opinion, this diligence to evolution and testing is the major “Magni Difference”.

## Addendum

### **HTL, CLT, LTL? (High Prop Thrustline, Centerline Prop Thrust, Low Prop Thrustline)**

So, if you have worked your way this far in this paper, I'm not sure you are anxious to start another technical subject. But if you are a gyro geek like me, always hungry to learn something new, you might want to plunge into the following "blasphemous" subject. If you have researched gyros very deeply at all, you have probably been exposed to all the emotional arguments and opinions on HTL, CLT and LTL. You may even understand all the discussions about center of gravity, pitch moments, thrustlines, balance of static moments, etc. You may have some strong opinions about what is best, CLT, LTL or HTL. I don't intend to get into all the technical derivations and customary arguments here. There are just a couple of points I don't think you may have been introduced to on the subject of prop thrustlines.

A couple of statements: Magni gyros are HTL – High Prop Thrustlines – by a number of inches! So are all the Magni "clones". By the popular static sum of moments analysis, this should mean that all these similar gyro configurations should be digging burning holes almost daily from static instability Power Pushovers (PPO, buntovers) and Pilot Induced Oscillations (PIO). This isn't happening! For the dynamic pitch damping reasons discussed above.

Now here's a second statement: HTL, CLT and LTL is no longer an issue with "Big Tails Way Back". Neither HTL, CLT nor LTL have the important airframe pitch dynamic damping without an effective horizontal stabilizer. Without a horizontal stabilizer, perfect CLT might be in balance, but it's an unstable neutral balance, and any slight disturbance can start pitch oscillations that will not be automatically damped – the pilot has to do it. And, perfect balance with CLT is almost impossible – don't eat a big lunch or use the restroom; don't use more than a couple inches of fuel in the tank! Without an effective horizontal stabilizer, both HTL and LTL would easily diverge in higher or lower airspeed without pilot intervention – skilled and constant pilot intervention – sometimes subconscious, but still muscle and brain work! With the incorporation of a good horizontal stabilizer, placed "way back" to multiply its effect on dynamic damping, close attention to prop thrustline is no longer a big concern. Prop thrustline is even less of a concern with a bigger tail further way back. If it were, certainly all the Magnis and Magni "clones" would be digging smoking holes. Can we all say "pitch dynamic damping"? This is what most producers outside the U.S. are doing – and they are breaking safety records and impressing all of aviation.

Here is a statement you will certainly have a hard time believing: HTL is airspeed stable. LTL is airspeed unstable! What you have been led to believe is that HTL is dangerously unstable. Certainly it is without a good horizontal stabilizer, but so are CLT and LTL without a good horizontal stabilizer – dynamic damper. That is no longer a concern with a "Big Tail Way Back" – strong dynamic airframe pitch damping makes them all stable and insulated from PPO, buntovers or PIO. But, aircraft designers would also prefer that aircraft be airspeed stable – if it starts to go faster, it automatically slows down. If it starts to go slower, it automatically speeds up – to its trimmed condition airspeed. You don't always want to be having to reign in airspeed if it starts to change.

With gyros, especially less stable gyros that tend to get less and less stable at higher airspeeds, it is important that they don't automatically try to go faster and faster at higher airspeeds. But that is exactly what LTL does. Here's why:

First, understand that some gyros perceived as "CLT" may actually be LTL. On a LTL configuration, prop thrust statically holds the nose higher, essentially slowing the aircraft slower than its actual trimmed condition. But, as airspeed increases, real prop thrust decreases – at high airspeeds prop thrust is much less than at lower airspeeds because of the faster incoming air. As it goes faster, the reducing prop thrust allows the nose to drop lower, increasing the airspeed. The faster it goes, the less prop thrust and the faster and faster it keeps going – for this situation, the pilot must actively slow the gyro with cyclic input to keep the airspeed from running away. The exact opposite is true if the aircraft is slowing down – it tries to go slower and slower as the prop starts to bite harder in the slower air raising the nose and slowing it down further. This is airspeed unstable; the airspeed does not automatically try to return to the intended trimmed airspeed, but instead continues to diverge from its trimmed airspeed.

On an HTL configuration, prop thrust statically pushes the nose lower, essentially speeding the aircraft faster than its actual trimmed condition. But, if the airspeed increases for some reason, the prop thrust decreases and allows the nose to rise, slowing the airspeed. If the airspeed decreases for some reason, the prop thrust increases and pushes the nose lower to increase the airspeed back to its trimmed airspeed. Upon increasing airspeed, HTL slows the airspeed by pushing the nose down less. Upon decreasing airspeed, the increasing HTL prop thrust pushes the nose lower to increase airspeed back to its trimmed condition. At higher airspeeds, or with pilot inattention, this can be an important attribute – it certainly reduces pilot workload that would otherwise always be having to monitor and correct airspeed constantly.

I would agree that HTL should be avoided if you just don't have a good horizontal stabilizer – just don't have good dynamic airframe pitch damping. But, with a good Big Tail Way Back, HTL is no longer a thing to be avoided. With a Big Tail Way Back, this benefit of HTL can be exploited, as it is in Magni gyros and all the "clones". Not to mention, with a Big Tail Way Back, designers no longer need to provide ladders to climb into the cockpit, or worry about tipping over so easily landing badly in a crosswind. If you do other things right – can you say Big Tail Way Back? – HTL can be a very good thing!

Thanks for your attention and diligence. Fly safe – Greg Gremminger