TIP-LAUNCH FORCE ANALYSIS

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Free Flight Tip Launch Gliders (TLGs) have been popular for many years, rapidly surpassing the traditional javelin (or baseball) style of launching. In our continuing quest to understand how to launch them higher and obtain that perfect transition from launch to glide we present some of our latest observations, theories, and understanding. This article assumes the glider is a Y-Tail design, held at the left wing tip, the launch is made by rotating the model counter clockwise, and the climb is to the left with a right turn in the glide.

The Launch before the release

To simplify the launching mechanics of the TLG we could envision Fig. 1, where the center of mass of our body is on the axis of a cylinder, looking from above this appears as the center of a circle, and the model is rotated at some radius from the center.

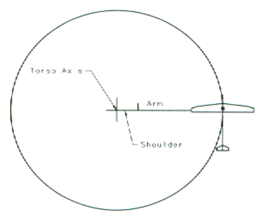

Figure 1
Simplifed Launch Mechanics

With this mathematical model we can calculate the centripetal force required to keep the model at this radius (How hard it is to hold a typical launch). The force is calculated by the formula:

F = m*v(squared)/r

F is the inward force required, **m** is the mass of the model

v is the velocity of the model

r is the radius of the circle the model is traveling

This formula assumes the model is rigid and calculates the force at the center of its mass. Inputting typical values for our models and making sure the units are consistent we obtain a force required of about 25 pounds. Here is the detailed calculation:

Typical Values

m=80 grams, v = 100 miles/hour

r =16" (wingspan/2)+4" (wrist)+ 12" (shoulder)+ 26" (arm)=58"

Now converting typical values to British Units

m = 80/453=.1766Ibms

v = 100*5280/3600=146.6 feet/second, r = 58/12=4.83 feet

Plugging in the numbers:

F = .1766*146.6"2/4.83=785.8lbm-ft/sec^2

Converting force into lbf

F = 785.8/32.2=24.4Ibf

From observations and photos we know that our models are not rigid; typically the tail boom bends a lot! The assumption of a rigid body is incorrect and a better mathematical model would be one that has two rigid bodies. The first rigid body extends from the fuselage nose to the trailing edge of the wing and the second rigid body extends from the wing trailing edge to the trailing edge of the Y-Tail (Fig 2).

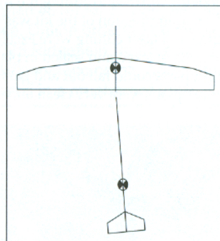

Figure 2
Two Rigid Body Model

Now with the same centripetal formula we can calculate the force at the center of mass of the second body (the boom and Y-Tail). For our typical carbon boom and a 17" tail moment this is about 3 pounds. We can apply this 3 pound force to the tail boom and measure its deflection, about 2". Wow, that is a bunch! Now we can understand why TLGs need such strong joints.

What happens in real life launching

We go through many motions during a tip launch but three of them seem important to this discussion:

A) Arc 3 is defined by the radius extending from the center axis of the human body to the center of the wing - twisting the waist (Fig 3).

B) Arc 4 is defined by the radius extending from the shoulder to the center of the wing: moving the arm (Fig 4).

C)Arc 5 is defined by the radius extending from the hand grip to the center of the wing: moving our wrist or the glider rotating about the grip (Fig 5).

Figure 3
Motion defined
by waist

Figure 4
Motion defined
by arm

Figure 5
Motion defined
by wrist

These arcs are simplifications of reality but they indicate the complicated motion our bodies go through during a tip launch. This complicated motion might look similar to Fig 6.

Figure 6
Possible motion
including the run-up
and spin

Arc 3 is important but mostly ends up coinciding with Arc 4 at release so we can ignore it for now. Arcs 4 and 5 are what it is all about, let us explain.

At release, before aerodynamic forces have time to "take over", the model must move tangent to Arc 4 and, ideally, the fuselage would be parallel to this tangent. However, besides holding the model in a misaligned manner, there is more than one arc to consider. If the tangent from Arc 5 is not parallel to the tangent from Arc 4 at release then the model will be out of alignment with the flight path. Also, if you have "flicked your wrist" this will impart an extra rotational motion, counterclockwise, much like throwing a flying disc.

As the model moves along the tangent to Arc 4 any misalignment, or rotational motion, will be resisted by the air. The majority of this air resistance is focused on the bottom of the right wing, due to dihedral, and the right side of the tail feathers forcing the model into a left roll. Because the tail feathers are at the end of a lever, the tail boom, and because most of their area is above the tailboom, the air resistance during a misaligned launch causes the boom to bend left and twist counterclockwise, dramatically (seen in many high speed photographs). Momentarily, while the boom is in this flexed and twisted state, most of the tail area acts like a huge left rudder! For an instant this amplifies the left yaw and coupled with dihedral it produces more left roll.

Now the tailboom snaps back, the right stabilizer skew and the right rudder offset take over. They cause the model to yaw right and consequently to roll right. It is a balancing act. We want all of the forces to put the model at the best attitude, as it runs out of energy, so that it can achieve the perfect transition to glide.

Decalage

Decalage: The longitudinal angular difference between the wing and the horizontal stabilizer. The positive decalage we use to attain stability makes our launch pattern be some part of a loop. The more positive decal age we use the smaller is the radius of this partial loop.

We discussed the huge left roll forces found at the release of the glider. Decalage is most powerful at the highest speed - when the model has the most left roll. This means that at the moment of the most left roll the positive decalage is causing the smallest radius partial loop and, seemingly, more left. It is common to think that the glider needs more right rudder offset or more stabilizer skew when it launches too far left. What might need to be done instead is to either throw more horizontally, so that the partial loop will be more vertically oriented, or reduce the decalage. There is one more possible solution: a stiffer tail boom. This may reduce the initial left roll and consequently the left appearing partial loop.

Adverse **roll (ADVR)**

What the heck? You've heard of adverse yaw but .... Ralph conceived of this one day and then had the annoying job of convincing us that ADVR is powerful enough to matter. It turned out to be a breakthrough in controlling TLG transition from launch to glide!

Adverse Roll is caused by the skew of the "V" dihedral stabilizer. This skewed V-stab is truly multifunctional: decalage for longitudinal stability, right yaw to initiate right turn, and ADVR, *which we don't want* (a minor exception will be explained later).

ADVR may be demonstrated quite easily: Simulate the glider fuselage with a light balsa stick, add a light Y-Tail with the stabilizer skewed dramatically. With the tail held high drop it. Watch it roll left- opposite the desired glide turn direction! Can this seemingly small force cause much of a problem? *Yes!* ADVR is the leading culprit responsible for that nagging stall, or two, just after the roll at the top of the launch. ADVR has the greatest effect just above glide speed, such as when the glider begins to dive just after a stall. At the moment the model needs to roll into the turn ADVR is trying to roll it away from the turn. This results in the glider flying straight for a bit, perhaps a stall or two, before it slows enough for the ADVR to be overcome.

So what is to be done? Reduce the stabilizer skew and increase the rudder offset (Rudder offset rolls the glider in the glide turn direction). Why not eliminate the skew altogether? Because it would take too much rudder offset to turn the model. This would not be safe; the glider would likely spiral into the ground when encountering a powerful thermal. This is also the reason why we want a little ADVR: it provides a little added resistance to this thermal spiral-in. Why not use tip weight for turn instead of stabilizer skew or extra rudder offset? No good, tip weight has too small an effect at transition speeds and spoils the glide.

Summary

Has any of this been proven? To our satisfaction, yes. We conducted many tests indoors and out with consistent results. We believe this knowledge helped in setting Stan's latest indoor world HLG record and winning outdoor HLG at the 2011 US Nationals.