Radio Controlled Soaring Digest

June 2014 Vol. 31, No. 6

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Front cover: Morgan Hill's ASH 31Mi at the 2014 Jerilderie Aerotow. Full coverage of this event starts on page 63. The story behind the transmitter in the cockpit is that the size of your sailplane has become a little bit of a status symbol, and the new benchmark is that if your transmitter doesn't fit in the cockpit – it's not big enough... Bit of a local joke.
Photo by Henryk Kobylanski.
Nikon D5200, ISO 100, 1/400 sec., f10, 78mm

Back cover: All-round slope glider Swing 88, span 2.2m, flying at Le Col du Glandon at 2000m of altitude in the French Alps.
Photo by Pierre Rondel
Canon EOS 650D, ISO 250, 1/2000 sec., f5.6, 300mm

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In the Air

Various types of lithium batteries have been available to the aeromodeling community for a number of years - LiPoly, LiIon, LiFe, etc.. Originally used for supplying the power to electric flight motor systems, with the advent of servos capable of handling higher voltages there is a growing trend to use lithium cells to directly power on-board electronic equipment. Two battery-related articles have appeared within the last few days...

First is an article which appeared in NASA's magazine "Tech Briefs" which explored power supplies for extreme environments and focused on Tadiran Batteries $LiSOCl_2$ cells. The Tadiran cells come in AA and AAA sizes, with the AA version capable of output pulses of 5A and recharging capability of more than 5,000 cycles. These cells are currently available from Digi-Key, House of Batteries, and Mouser Electronics. See the Tadiran website <http://tadiranbat.com> for further information, cell terminal options, and a complete list of distributors.

The second article appeared in GizMag.com. The Japanese company Power Japan and Kyushu University have announced the development and planned mass-production of a disruptive dual carbon battery that can be charged twenty times faster than an ordinary lithium-ion cell. Power Japan is planning to produce the battery using an organic carbon complex, developed in-house from organic cotton, to obtain a greater control over the size of the carbon crystals in its electrodes. Originally destined for use in electric automobiles, photos on the GizMag page portrayed what appears to be a AA cell along with a couple of flat cells. See <http://www.gizmag.com/dual-carbon-fast-charging-battery/32121/>.

Time to build another sailplane!

B²

Bell-shaped versus elliptical lift distribution wings

A few translations of basic mathematical aerodynamic truths into physical explanations

Proverse roll-yaw coupling

and flying the undersides of shifted lift/drag curves.

Philip Randolph, amphioxus.philip@gmail.com
Profili plots by Adam Weston

Where to: BSLD wings. Proverse roll-yaw coupling.

I've split this article into two parts. First is a discussion of the structural and aerodynamic efficiency benefits of bell-shaped lift distribution (BSLD) wings as pioneered by Ludwig Prandtl in a 1932 paper, as compared to elliptical lift distribution (ELD) wings. Much of the article covers basics, especially trailing vortex pressure drag, necessary for our next step.

Second is a look at wings that will perform coordinated turns without a rudder – proverse roll-yaw coupling. The pioneers here were Walter and Reimar Horten. The Horten brothers, from 1933 – 1950, working in pre-war and WWII Germany and later in Argentina, designed and built tailless flying wings that achieved proverse roll-yaw coupling via BSLDs. Because of their work, discussions of proverse yaw are usually linked with BSLD wings and their structural and aerodynamic benefits of BSLD and with 'tailless' aircraft, 'flying wings.' For achieving a combination of efficiency, light weight per structural strength, and proverse roll-yaw coupling BSLD is one ideal, but in the aero world of compromises there are other options. The basics important here are wingtip vortex upwash and the use of lift/drag curves to predict proverse yaw.

In the two halves of the article we'll separate the influence of trailing vortices and wingtip vortices.

• Trailing vortex pressure drag: Drag is mainly from trailing vortices. If we're talking about comparative drags of BSLD and ELD wings, we look at trailing vortex pressure drag. That's a major tool for the first part of the article.

• Wingtip vortex upwash: Roll-yaw coupling of BSLD wings is related mainly to wingtips flying within the upwash of wingtip vortices, plus adverse drag influences of trailing vortex pressures, and ultimately to adjusted lift/drag curves. These are the tools for our second half, proverse roll-yaw coupling.

Right up front I have to say I am not completely sold on 'pure' BSLD wings. That means I'm somewhat objective. BSLD wings may have applications. The concepts innate to comparisons of BSLD and ELD wings are important. The compromises and approximations of BSLD do have applications. Most airliner wings are not purely ELD. They narrow the lift distribution near wingtips for structural reasons,[1] a slight shift toward BSLD.[2] Then commercial designers add

1 According to a 4/27/2014 conversation with S. Allmaras, Ph.D.

2 Ludwig Prandtl, in the 1932 article and diagram discussed later in this article, diagrammed a compromise between ELD and BSLD. And Robert T. Jones, in his *Wing Theory*, elucidated the benefits of

winglets, which if horizontal would be another tilt toward BSLD. Please see the section on ELD-BSLD compromises.

To some extent the timing of BSLD implementation is backwards. BSLD wings optimize lightweight structure, usually measured by root bending moment, for a given lift. And that helps with fuel efficiency. But structural weight considerations are most important with weak materials – bird muscles, tendons, and bones; the willow sticks of Otto Lilienthal's gliders; or wood and fabric. To some extent aluminum and then carbon fiber allow great strength with little weight penalty from varying from optimal lift distributions.

On a strength continuum from 98-pound weakling getting sand kicked in his face at the beach to Spiderman strong, modern materials are partway to fictional-but-ideal materials of infinite strength, where varying shape would make no weight penalty. On the other hand, in a non-stop flight of 8,000 miles, every bit of weight savings makes fuel savings.

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that compromise. (Robert T. Jones, *Wing Theory*, Princeton University Press, 1990, 113–114.) Also see the diagram on page 16 of: (Bill Kuhlman, "Twist Distributions for Swept Wings, Part 4," *Radio Controlled Soaring Digest*, June 2003, 16, http://www.rcsoaringdigest.com/OTW/on-the-wing4/164-HCP4.pdf.)

A tertiary benefit: Writing the article made me clean up more of my basic aerodynamic understandings. So it has been educational, and should be for readers.

In the history of aerodynamics there have been many neglected approaches. To bring a historic idea into acceptance requires an advocate. Albion Bowers, Deputy Director of Research at NASA, Dryden, is that advocate for the Horten's approach and the structural, efficiency, and proverse yaw benefits of BSLD wings. You can find his TED talk at:

http://www.youtube.com/watch?v=223OmaQ9uLY

There is also excellent, ongoing discussion at the *Nurflugel* ('flying wing') Yahoo discussion group, in which Albion Bowers frequently comments. It's at:

https://groups.yahoo.com/neo/groups/nurflugel/info

This article has thoroughly benefited from the discussions on *Nurflugel*. Extensive information about BSLD wings and how the upwash outboard of wingtip vortices affects proverse roll-yaw coupling has been presented there. If I've unintentionally scooped anyone's serious research I'm happy to yield precedence. I have been privy to information I conceptually disagreed with and did not repeat. What I've repeated has been part of the very general discussion. For example, it is well understood that flying aileron-equipped wingtips in vortex upwash can produce proverse yaw forces.

There are a few areas within which I have independently derived contributions (which doesn't at all mean that I thought of them first):

• First and most basic is an explanation of wingtip/trailing vortex formation and 'trailing vortex pressure drag' as a foundation for how the wingtip and trailing vortices affect roll-yaw coupling via thrusterons and dragerons.

• Second is clearing up basic misunderstandings about the forces wings put on air, the forces that create wingtip/trailing vortices: I show that by 'downwash' Prandtl meant 'net-downwash,' and show that three concepts are equivalent: Prandtl's (net) downwash, Prandtl's induced angle of attack, and Lanchester's sinking vortex.

• Third (and the second part of the article) is the use of lift/drag polar curves to predict roll-yaw coupling. I posted the beginnings of this approach on the *Nurflugel* site (8/22/2013).[i] Here I add how the curves shift upon aileron deflection and location in vortex upwash. Preview: Proverse roll-yaw coupling forces happen when roll-control surfaces are located in wing areas flying in negatively sloped areas of the lift/drag polar curves. Even in vortex upwash that only occurs in wing segments that are lightly or negatively loaded.

There is still a great lack of information. For bell-shaped lift distribution wings (BSLDs) there have not been published wind-tunnel smoke-stream photos or sophisticated CFD analyses that show trailing vortex pressure profiles, nor 'crossover points' (different from trailing vortex centers!). The true experts will probably change that soon. (Outboard of the crossover point flows slope upward. A bit of winglet in that upward flow can gain thrust in the same way that a glider gains thrust from thermal updrafts.) Prandtl diagrammed the crossover point at about 70% of half-span. (See his diagram.) My very questionable modeling with XFLR5 indicated the crossover point at about 80% of half-span. An aerodynamics Ph.D. friend informally estimated the vortex center at 91% of half-span. (That may also be suggested by the BSLD elliptical net-downwash pattern in figure 2!) In the BSLD illustrations I've stuck with Prandtl's 70% for the crossover, and about 2/3 half-span for the vortex center. For reality we'll have to wait for the quantitative guys.

Fishing for clarifications, corrections, and good information.

Disclaimer: Artwork herein is for conceptual purposes. It is generally not to scale. If anyone out there can correct it or put it into correct scale, please contact me.

Comments, corrections, quantifications, or supplemental graphical or CFD analyses: Please. If you've got expertise I'm happy to give credit.

BTW, I'm writing a book, mostly on great historical aerodynamic theories that were bypassed either for no good reason or because they predated the supercomputers required to turn them into engineering.

BSLD wings

Elliptical versus Bell-shaped lift distribution wings: design optimization follows design parameters

In aerodynamic engineering the question determines the answer. An early question was, "What wing planform is the most efficient?" Answers to such questions are determined by choice of constraints. The simplest constraint was picked first – wingspan. It's not the constraint that gives the best answer, unless, of course, wingspan really is a constraint -- for example, Standard Class gliders maximum span is 15 metres. Discus launch model glider competitions (DLG) are limited to 60". The prevalence of competition classes limited by span biases design efforts toward a commonplace focus on elliptically loaded wings.

In 1908, published in 1918, Ludwig Prandtl developed the elliptical load distribution.[ii] Wingspan, airfoil, and load were held constant. Prandtl determined that for a given wingspan an elliptical lift distribution (ELD) yielded the most efficient flight. Which is true. However:

A decade later Prandtl questioned whether he had picked optimal design parameters. In a 1932 paper he attempted to approximate the answer to a more sophisticated question, "For the same lift, spar weight, and wing-root bending moment (strength) as an elliptical wing, what lift distribution and span offers the greatest efficiency?" His answer was a bell-shaped lift distribution (BSLD). With a 22% increase in span the BSLD wing was just as light and strong as the ELD wing and carried the same load with about 11% less induced drag.

See Figures 1, 2 and 3

The Horten brothers, from 1933 – 1950, working in pre-war and WWII Germany and later in Argentina, designed and built tailless flying wings that used 'bell-shaped lift distributions,' or BSLD. In addition to structural and efficiency benefits, their aircraft achieved coordinated turns without the use of a rudder, or 'proverse roll-yaw coupling.' That's our second article. In this first article we'll cover basics.

The Hortens achieved BSLD with a combination of planform, twist (washout) and airfoil changes along span (aerodynamic twist). They weren't the first to do use all three design elements – a May 2014 article in *Air & Space* describes a swept-wing, tailless biplane

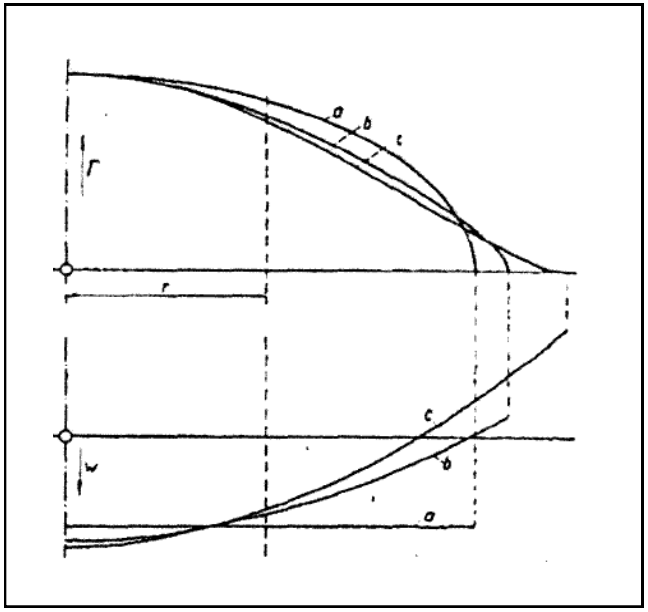
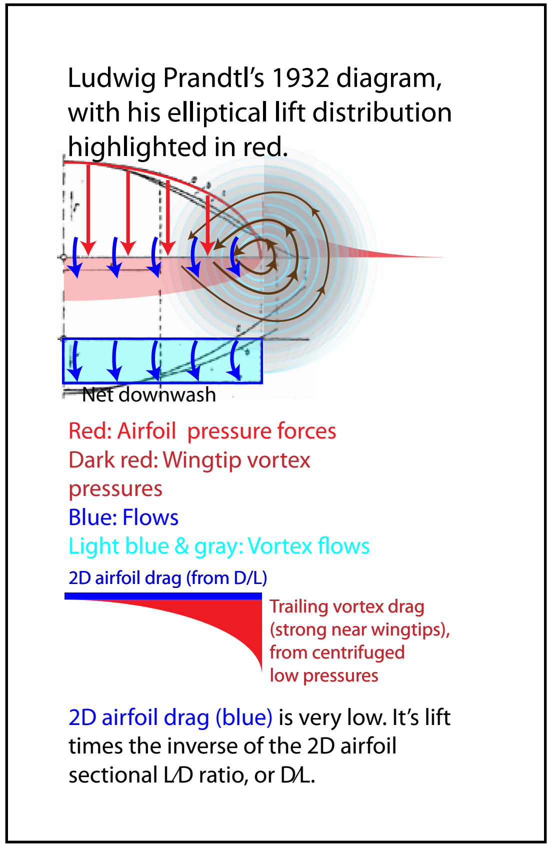


Figure 1: Prandtl's 1932 diagram of elliptical and bell-shaped lift distributions



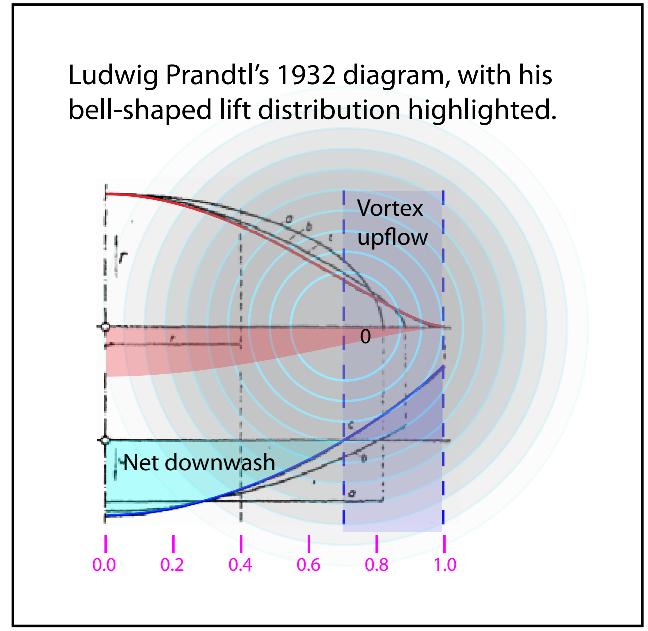


Figure 3: Prandtl's 1932 diagram with bell-shaped lift distribution highlighted

designed by Starling Burgess in 1912. Google images show significant twist near wingtips, where he used thickened airfoils. It did rely on large 'end curtains' between its biplane wingtips for yaw stability but was rudder free, a step toward tailless coordinated flight.

And BSLD? Any wing with twist will, at some wing loading and angle of attack, loosely approximate BSLD. It may require very light Gs, such as when pushing over at the top of a high-speed arc. When a combination of speed and low angle of attack put the twisted wingtip at zero-lift AoA BSLD will at least be approximated.

Figure 2: Prandtl's 1932 diagram with elliptical lift distribution highlighted in blue. Actual net-downwash velocities near wingtips are curved because of the pressure gradient around the end of the wing, but perhaps 'rectangular downwash' refers to the vertical component of net downwash. Wingtip vortices are asymmetrical and only partially formed. The wingtip partial vortex is formed by pressure gradients and by sheer of downwash flows with upflows. Downwash flows and the pressure gradient around the wingtip help form the wingtip vortex, not the other way round. As the wingtip vortex becomes the trailing vortex it centrifuges a low-pressure center which 'pulls' back on the wing and helps defeat pressure energy recovery near the wingtip. It's important to distinguish between: (1st) Pressure forces exerted by the wing (red) which are always normal to its surface; (2nd) Pressure forces around the wingtip (dark red); (3rd) Resulting flows (blue, light blue & gray).

And any wing designed for BSLD will stray from that optimum at different speeds. The Horten designs used a lot of twist. If designed to have wingtips at zero-lift AoA in takeoff, when AoAs are highest, at the lower incidence of cruise speeds wing twist would make tips lift negatively. If designed with twist for BSLD at cruise speeds, during takeoff and landing higher AoAs would put wingtips in positive lift, which could challenge the wing's proverse roll-yaw coupling capabilities. A rudder might be necessary. But the lift distribution would be between elliptical and BSLD. That's like having more wing for takeoff and landing.

And then there is inverted flight. Wings that achieve BSLD via twist don't like it. Upside down, the twisted BSLD wingtips find themselves at high positive angles of attack, making tip stalls. That will either lead to a roll to upright or to a spin. For aerobatics tiperons off an untwisted or lightly twisted wing could work.

BSLD may be attempted by planform alone, making a wing with a bell-shaped profile as viewed from above. But then the very narrow tips operate at low Reynolds numbers, potentially making other problems.

Terminology, and how the trailing vortex makes high wingtip drag:

First, basics: we now look at the mechanisms of what should properly be called 'trailing vortex drag.'

> "Deflected ailerons deform the load distribution away from the ideal near-elliptical shape, and hence increase induced drag.[iii]" – Mark Drela, quoted by kcaldwel on RC Groups.

The drag on wings is from pressure or friction. Most of the drag on fractional subsonic wings is from pressures. And most of that is from the lowered pressures in the trailing vortex. Terms will get us to how that works:

• *'High wingtip drag'* is a correct term that merely indicates that drag is usually highest near wingtips, at least for elliptical lift distribution wings. BSLD wings have the highest vortex drag somewhat inboard of wingtips.

• *'Wingtip vortex drag'* is an incorrect term; the wing puts forces on air to make the wingtip vortex, but the wingtip vortex *mostly* doesn't put *drag* forces on the wing. (Well, actually all wing-caused forces have 'interference' affects on all other parts of a wing. Lift forces form vortex forces which leak spanwise. Wingtip vortex forces on vortex upflows are critical to BSLD thrust and thrusterons. Still, the actual drag forces on a wing are not from the wingtip vortices, but from pressures within the trailing vortices.) We'll examine this in detail.

• *'Trailing vortex pressure drag'* is a correct term. The low-pressure center of the trailing vortex 'pulls' back on the wing (mainly near the wingtip) and the air surrounding it, reducing pressure energy recovery. It also 'pulls' forward on trailing air, with the equal and opposite force.

The low-pressure center of the trailing vortex is created in two ways. First, pressure energy is used up creating the circular velocities of the wingtip vortex. Where the velocities are highest, near the center of the vortex, pressures are lowest. Second, as the wingtip vortex becomes the trailing vortex its rotational velocities centrifuge its core pressures even lower.

The energy input per second required to keep a plane moving forward is equal to the energy-per-second lost to wake. In the wake that energy is a mix of trailing vortex pressure gradients pulling forward and inward on air, and resulting forward and rotational wake air velocities, plus turbulence and heat.

Lanchester pictured his wingtip/trailing vortices centered near wingtips, accurate for most wings. For an ELD wing the crossover from downflow to upflow happens close to the center of a 'wingtip' (sic) vortex and roughly at or a little in from the wingtip. The 'crossover points' of Prandtl's 1932 BSLD wings are centered well in from wingtips. (For a BSLD wing the crossover happens just outboard of the vortex center.) However, in his 1932 article Prandtl didn't mention vortices. He approached the problem in a more mathematical manner.

See Figures 4 and 5

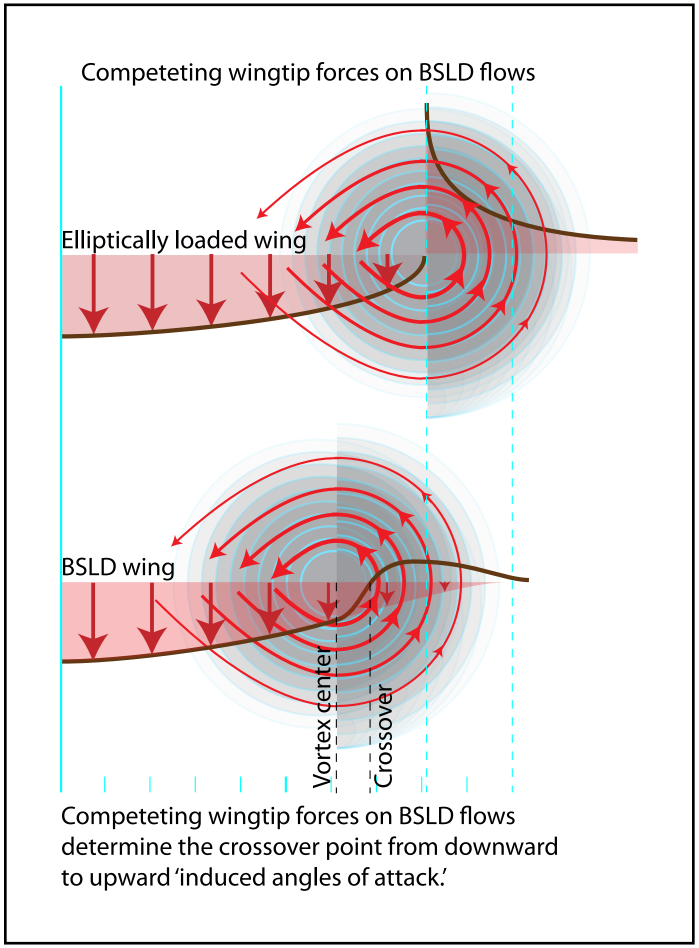


Figure 4: The forces that determine the crossover point. Outboard of the BSLD wing crossover point, wingtip vortex upward pressure forces exceed downward lift forces on air, for a net upward force on air. That makes the rising flows within which a BSLD wingtip may gain thrust. The vortex center doesn't make an upward or downward force, so at the vortex center downward lift forces on air are unopposed. Therefore a BSLD wing's crossover point to upflows is always outboard of the vortex center.

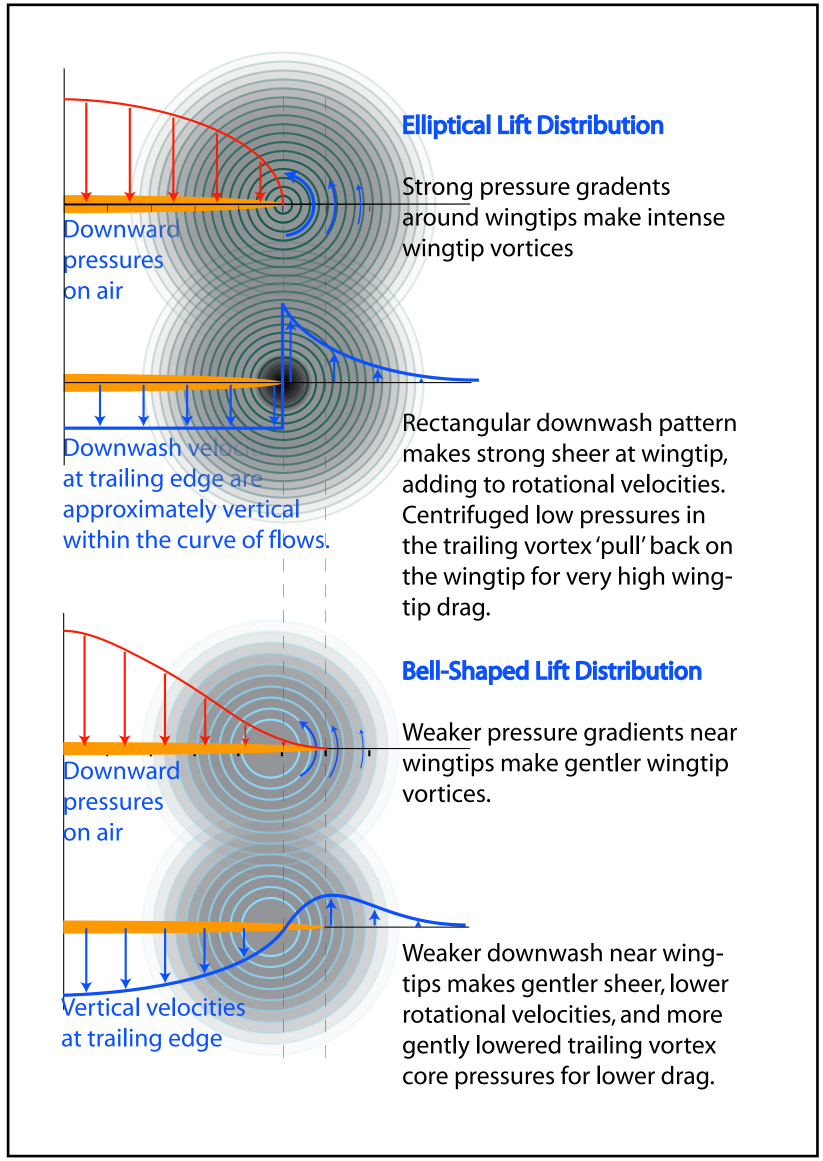


Figure 5: Lift forces on air and net-downwash. Bell shaped lift distribution wings create gentler trailing vortices for lower trailing vortex pressure drag. Their wingtips ride in vortex upwash. Red arrows show lift pressure forces. Blue arrows show net-downwash momentums.

To make thrust, BSLD wingtips must overcome trailing-vortex pressure drag. A primer on how trailing vortices make pressure drag.

The accompanying XLFR5 plot shows negative induced drag, or thrust, outboard of about 80% of a BSLD wing half-span. I used XLRF5's VLM, or Vortex Lattice Method feature. Unfortunately when running the more sophisticated XLFR5 features, viscous analysis and 3D analysis, it announced errors. And when I had it build a graph of 'induced drag' (vortex drag) for an ELD wing it didn't show high wingtip drag. So whatever it was doing was suspect. XLFR5 is phenomenal wing analysis freeware, but please take that 80% 'crossover' from drag to thrust and the pattern of 'induced' drag (trailing vortex pressure drag) with a grain of salt. Supercomputer CFD results would be more trustable. Still, it's illustrative. And leaves a mystery.

See Figure 6

When one designs a wing, whether in XFLR5 or some industrial CFD program, one can ask for a graphic of drag by span. That's great. XFLR5 will even animate, so you can watch how drag changes with angle of attack. For a BSLD wing, near the tips, you can see how drag is negative, meaning the wingtips can produce thrust. And it's possible to do all that without having an idea of what the various influences are around a wing, what causes what, and how they add up to the total effect you are watching on your computer screen.

To start to get a grasp on how various wings work it's necessary to understand the various forces and momentums at play. One needs to investigate just how the wingtip/trailing vortex system forms, where it is located on the wing, and the pattern of its pressures and velocities. And to do that we have to chase some old ideas about what 'downwash' means or should mean.

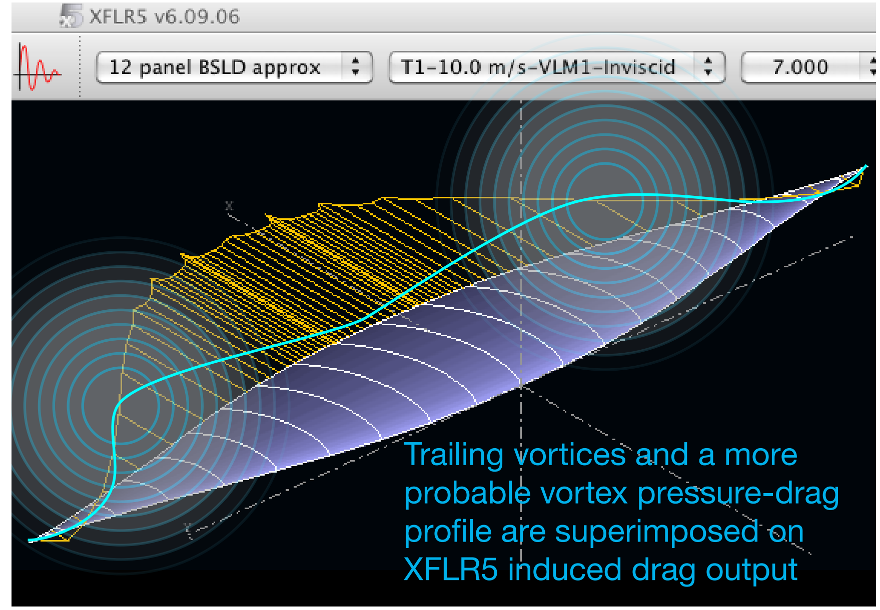


Figure 6: XFLR5 BSLD 7° Vortex Drag, with trailing vortices and a more probable vortex drag superimposed. XFLR5 inviscid VLM very approximate but illustrative plot of 'induced' drag of a BSLD wing. 'Induced' drag should be a map of trailing vortex pressure drag, and thus an approximate map of trailing vortex pressures. Meaningful accuracy would require an industrial CFD program or wind tunnel results. Note the areas of negative drag or thrust near wingtips. Also note the drag spikes. Vorticity and vortex pressure drag increase wherever there is a sudden change in lift, as at the junctures between trapezoidal wing sections. Anyone who can supply a more accurate plot, please contact me.

Basics: What did Prandtl mean by ‘downwash?’ (Net downwash.) Prandtl’s (net) downwash and ‘induced angle of attack’ as equivalent to Lanchester’s assertion that airplanes always fly in sinking air (with the exception of Prandtl BSLD wingtips!)

Another case of good math making good results even when applied to questionable physical understandings.

First we’ll look at truths that mainly date to Frederick William Lanchester’s work from 1894, 1897 and 1907: Lift is from the reversal of upwash momentums ahead of a wing to slightly greater downwash momentums aft (per second). The difference is net downwash. Net downwash contributes to lift, but also carries energy into a wing’s wake, part of the energy that must be replaced by thrust to keep a plane moving forward.

See Figure 7

That a wing loses energy to its wake is equivalent to three nearly synonymous but seemingly disparate descriptions.

• First: All airplanes fly in sinking air, in a ‘sinking-vortex’ pattern. That makes flight like walking up a sand dune, with sink at every step. Energy lost to wake implies sink. Lanchester diagrammed a wing flying in air that sinks inboard from its wingtips and rises outboard of its wingtips.

See Figure 8a

An airplane’s weight, exercised through the action of the wing, makes air inboard from the centers of its wingtip vortices sink. Viewed from ahead the wing flies in a sinking vortex (though wingtips may stick into rising air). Lanchester, a physical intuitionist, generally had causally correct analyses.

See Figure 8b and 8c

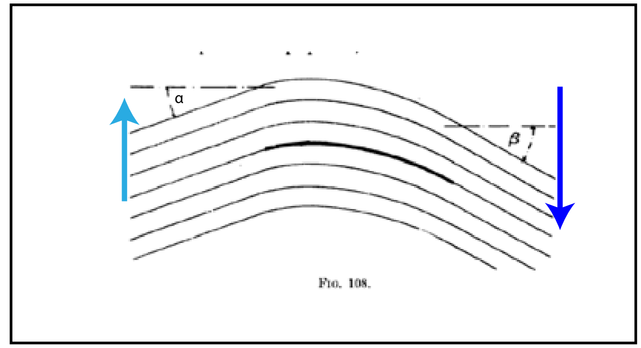
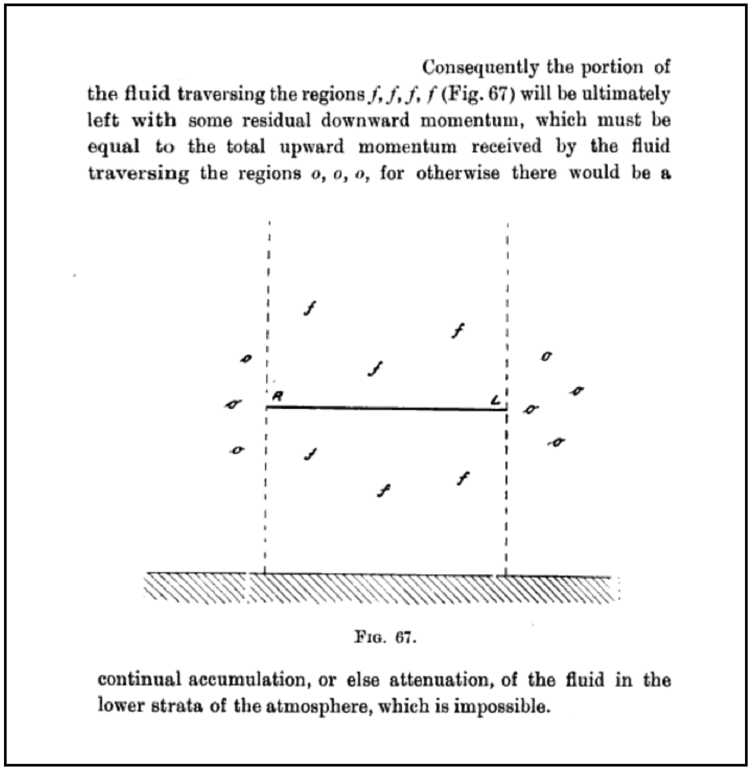


Figure 7: Frederick William Lanchester’s 1907 diagram showing greater angle and velocity of downwash than upwash. Lanchester correctly asserted that lift came from upwash momentums ahead of a wing being reversed to greater downwash aft. Although he was first to visualize an idealized ‘circulation’ around a wing he was too realistic to be a true believer in ‘bound vortex’ symmetry. He translated wing-flow waveform into ‘circulation,’ but didn’t believe literally in the useful but idealized symmetry of either.



Consequently the portion of the fluid traversing the regions *f*, *f*, *f*, *f* (Fig. 67) will be ultimately left with some residual downward momentum, which must be equal to the total upward momentum received by the fluid traversing the regions *o*, *o*, *o*, for otherwise there would be a

Fig. 67.

continual accumulation, or else attenuation, of the fluid in the lower strata of the atmosphere, which is impossible.

Figure 8a: Lanchester's 1907 diagram showing sink (f f f f) inboard of wingtips and rising air (o o o) outboard of wingtips.

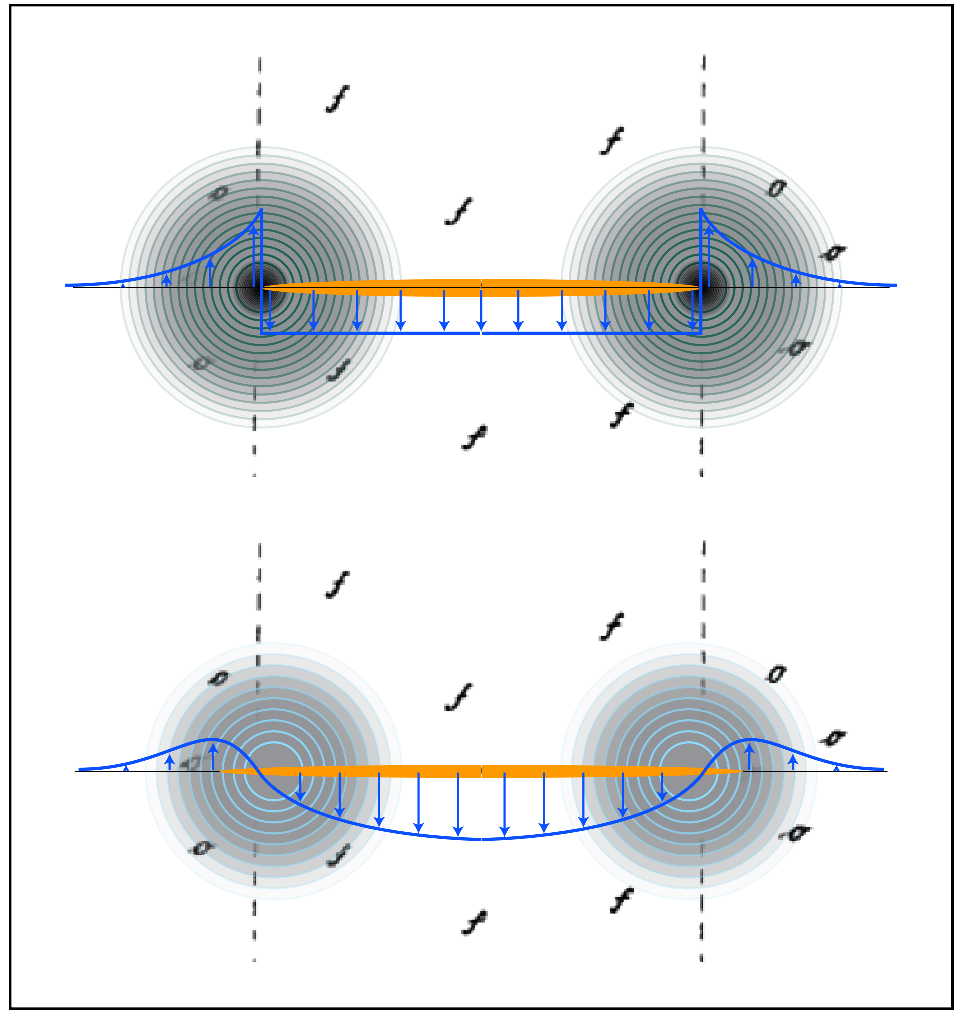


Figure 8b: Lanchester's 1907 diagram with equivalent downwash patterns superimposed:
Upper: Elliptical load distribution wing has rectangular net-downwash
Lower: Bell-shaped load distribution wing has net-downwash inboard of 'crossover points' and 'net-upwash' outboard of crossover points.

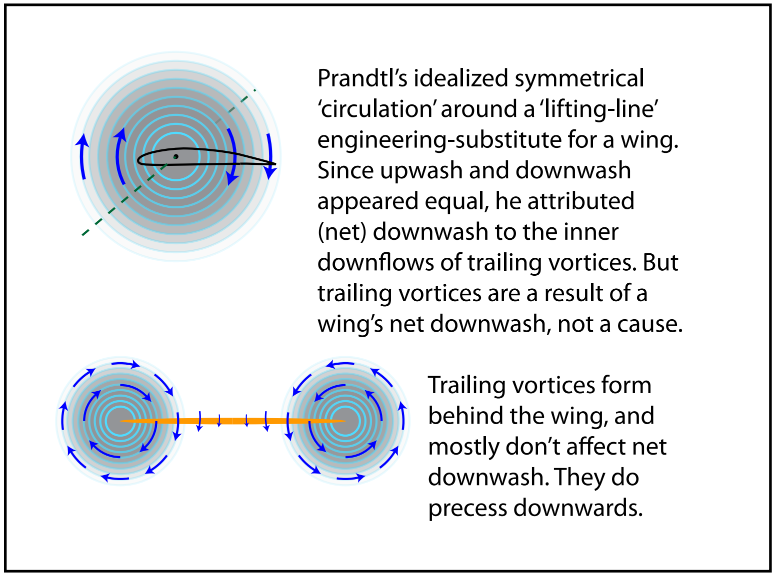


Figure 8c: Prandtl's causally backwards explanation of (net) downwash.

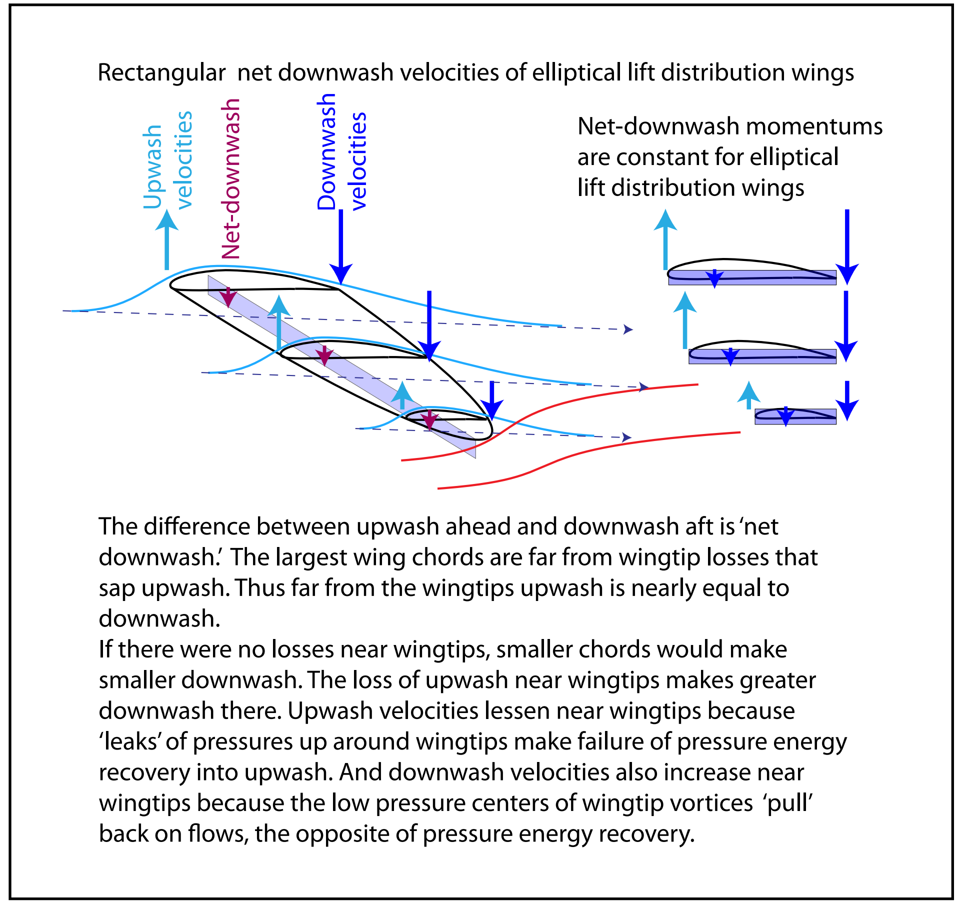


Figure 9a: Net downwash. Local net downwash is from differences between upwash ahead and greater downwash aft.

• Second: 'Net-downwash.' For the entire span of traditional wing sections, downwash momentums aft are always somewhat greater than upwash momentums ahead. The difference between vertical momentums of upwash at the leading edge and downwash at the trailing edge is 'net-downwash.' BSLD wingtips have net upwash.

See Figures 9a and 9b

The idea that elliptical wings have a rectangular pattern of net downwash momentums was developed mathematically by Prandtl in the second decade of the last century. Figure 9c attempts a physical, causal explanation.

See Figure 9c

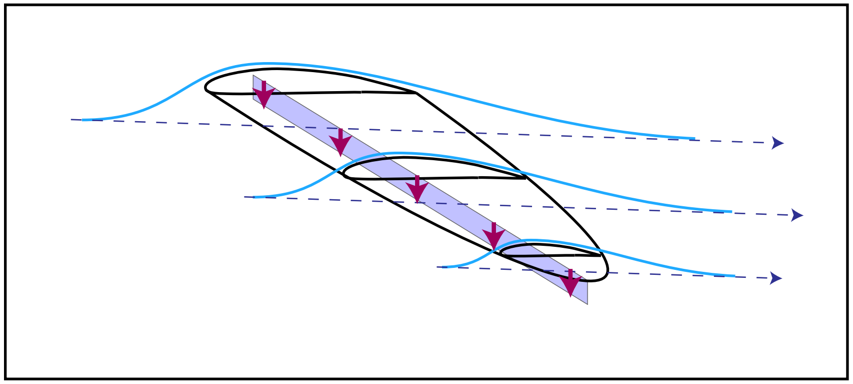


Figure 9b: Rectangular net-downwash of elliptical lift distribution wings. Many aerodynamics texts consolidate upwash and downwash into net-downwash at the quarter-chord, Prandtl's 'lifting line.' Unfortunately this net-downwash is often simply called 'downwash,' which leads to confusion of 'net downwash' with 'trailing-edge downwash' and to forgetting that lift comes from reversing upwash momentums ahead to downwash momentums aft.

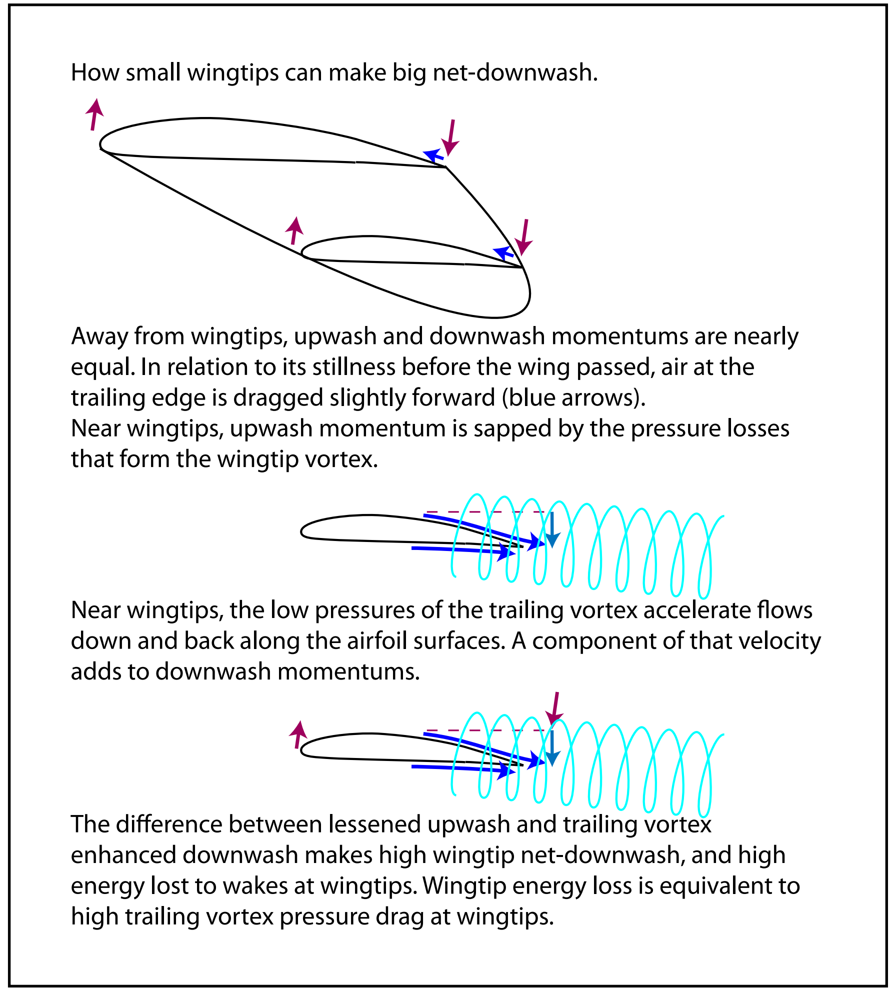


Figure 9c: How narrow ELD wingtips can make 'rectangular' net-downwash. If these were 2D wing sections in a wind tunnel, and one had twice the chord of the other, part of the answer would be that the air at the surface of the smaller section drops half the distance in half the time, for the same vertical velocity at the trailing edge. That's deceptive. The larger wing section affects a larger volume of air, and so would create greater net-downwash momentum. A real wingtip has less upwash because of wingtip losses of pressure differences between upper and lower flows. And its downwash is increased as air is not only accelerated downward but is also accelerated at a downward angle backwards toward the low-pressure center of the trailing vortex. Theoretical net-downwash remains constant along the span of elliptical wings.

• Third: 'Induced angle of attack' and 'sink': The 'induced angle of attack' is the local downward angle of flow an ELD wing encounters because the air it rides in is sinking. The induced angle of attack is theoretically constant along the span of an elliptical wing. The induced angle of attack varies along BSLD wingspan, and becomes positive outboard of the 'crossover point,' where wingtip vortex air is rising.

• Also third: 'Induced angle of attack' and 'net-downwash.' Net-downwash velocities can be translated into induced angles of attack: We make vector sums

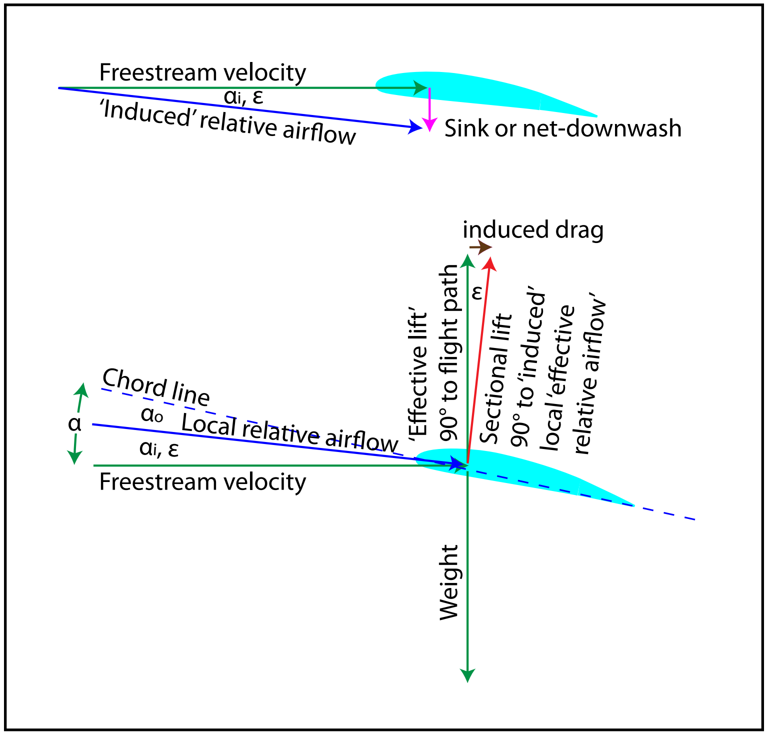


Figure 10a: For each wing section, the vector sum of the freestream velocity and net-downwash (or its equivalent, sink) yields the 'induced' angle of local 'effective relative airflow' or 'relative wind,' and the 'downwash angle,' ε, equivalent to the 'induced angle of attack, α_i. For ELD wings the induced angle of attack is downward for all sections.

Sectional lift forces are perpendicular to the 'induced' local flow or 'effective relative airflow.' A component of this sectional lift force is in the direction of drag, and a component is opposite to weight, making effective lift. To stay up, wings have to angle up so that their zero-lift line is steeper than the average (negative) angle of attack.[iv]

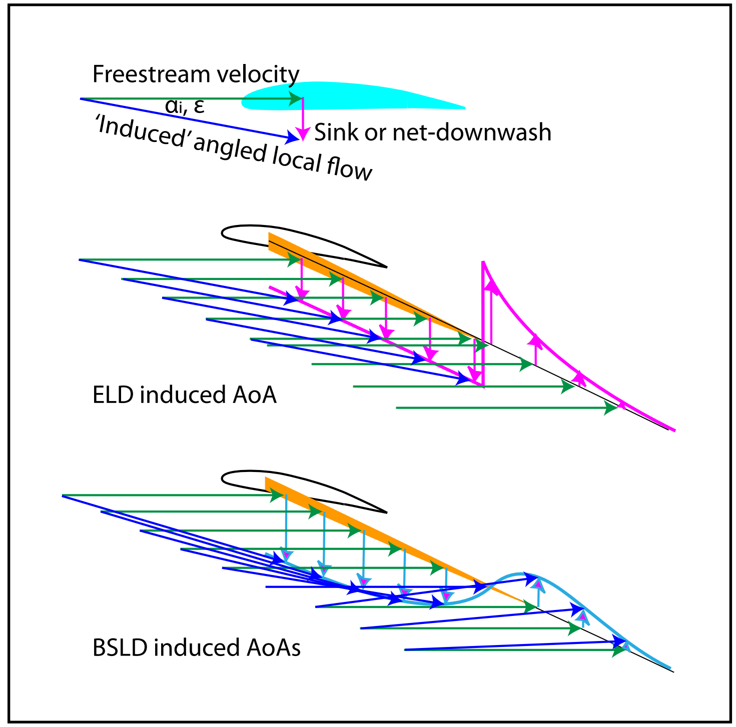


Figure 10b: Induced angle of attack is positive for BSLD wingtips.

of the wing's forward speed and local 'net-downwash' velocities (or, outboard of the 'crossover point,' 'net-upwash' velocities.

See Figures 10a and 10b

Prandtl's causally backwards idea of 'downwash.'

Prandtl's idea that a wing encounters down-flowing air is equivalent to Lanchester's more physically accurate diagrams showing that an airplane always flies in sinking air. Prandtl, as a mathematical engineer, built methodologies that gave engineering results with correlations confused as causalities.

Within aerodynamics misinterpretations abound. In this section we'll see a common misinterpretation of Prandtl's 1932 diagram. It (probably) accurately shows elliptical lift distributions making constant (rectangular) ‘downwash’ (momentums), and bell-shaped lift distributions making elliptical downwash momentums. Unfortunately, at least in that paper, Prandlt wasn’t clear about what he meant by ‘downwash,’ though it can be parsed that he meant ‘net downwash.’

Prandtl substituted his highly artificial (symmetrical) ‘bound vortex’ engineering idea for a wing. His idea was that his symmetrical bound vortex couldn’t make vertical velocities, so his rectangular ‘downwash’ must come from the inner, downward velocities of the trailing vortices.[v] That is technically equivalent to saying that the upwash and downwash of the bound vortex are equal (false), while net downwash is *caused* by the trailing vortices (false again, and causally backwards).

Rather, the flows, forces, losses, and pressure-energy recoveries around a wing are asymmetrical and *cause* net downwash and create the trailing vortex system, not the other way around.

To assert that the trailing vortices cause net downwash is a bit like pulling a bucket out of a well, and then claiming that since there is a net force upward the bucket must be pushing the rope up. It’s as if Prandlt was self-hoisting on his own petard and claiming that he, rather than his backward causality, was the lifting force. In the mythical ‘lifting oneself by one’s bootstraps’ the equivalent notion would be that the boot puts the upward force on the strap.

We could split Prandtl’s ‘circulation’ approach into two parts. *If* ‘bound vortex’ ‘circulation’ were symmetrical (it isn’t), it would have upwash equal to downwash, and by Kutta-Joukowsky would make lift without losses. Second, if the (net) downwash were *from* trailing vortex action (false) rather than from the action of the wing, then net downwash *wouldn’t* contribute to lift but *would* be part of losses of energy to wake. Actually, the ‘net’ downwash thrown down by the wing does contribute to lift, but also is part of the energy losses to wake. Net downwash is the expensive part of lift creation.

And yes, trailing vortices do precess downwards, in the sinking or traveling vortex pattern typical of smoke rings. But that’s another result of the wing forces that set up the vortex motions, and not a cause of net downwash.

Prandtl’s idea that trailing vortices create net downwash has another flaw. Trailing vortex velocities roughly follow the rule that V = k/r, except near the center of each vortex, where velocities are more proportional to radius. Such vortices would not make a rectangular net-downwash velocity pattern. Again, it is the wing that makes the wingtip/trailing vortices, not the other way around.

See Figure 11

Even though Prandtl’s idea that trailing vortices cause net downwash was causally backwards it was mathematically passable. Engineering requires only quantitative knowledge of ‘what happens’ rather than ‘why’ or ‘how.’

The wingtip and trailing vortices and trailing vortex pressure drag

Note: I use the term ‘trailing vortex pressure drag’ because it’s accurate and explanative. The usual terms are ‘induced drag,’ ‘vortex drag,’ or ‘high wingtip drag.’ These terms are often expressed vaguely in terms of ‘energy’ going into wingtip vortex formation. While that can be made to add up, drag is a *force* and the force is pressure difference on wing area. ‘Trailing vortex pressure drag’ makes this explicit.

We can divide wingtip/trailing vortex formation into the forces that create the wingtip vortices, wingtip vortices, and trailing vortices.

The components of pressure forces that make the swirl of wingtip vortices are in the y-z plane (the vertical plane crosswise to a plane’s travel, up through the quarter-chord of an unswept wing). This is the pressure gradient around wingtips, from slightly raised below to lowered above. These forces are like a spade bit in a drill used to stir your coffee, or a single beater in your eggbeater. Unlike a propeller, they impart a rotary force without adding thrust.

Okay, true, ahead of the wingtip air is accelerated both in a swirl and up toward the low pressure atop the wing. So it speeds up. With poor pressure recovery near wingtips some of that speed remains in the trailing vortex flows, rather than transforming back into pressure. So that's one reason there is low pressure in the center of the trailing vortex that drags back on a wing. But we're going to focus mainly on the y-z plane forces.

The pressures that form the wingtip vortex extend ahead and outward from the wingtip. They are a mix of the x-z pressure gradients that form upwash ahead of a wing and the y-z pressure gradient around the tip of a wing. These pressures make the wingtip vortex swirl up and around the end of the wing. The vortex (y-z) component of motion around the end of the wing lowers pressures below the wingtip and raises pressures above the wingtip. Pressure gradient energy is exchanged for rotational velocity energy. This is another way in which pressures are lowered in what becomes the center of the trailing vortex. Again, the lowered pressures

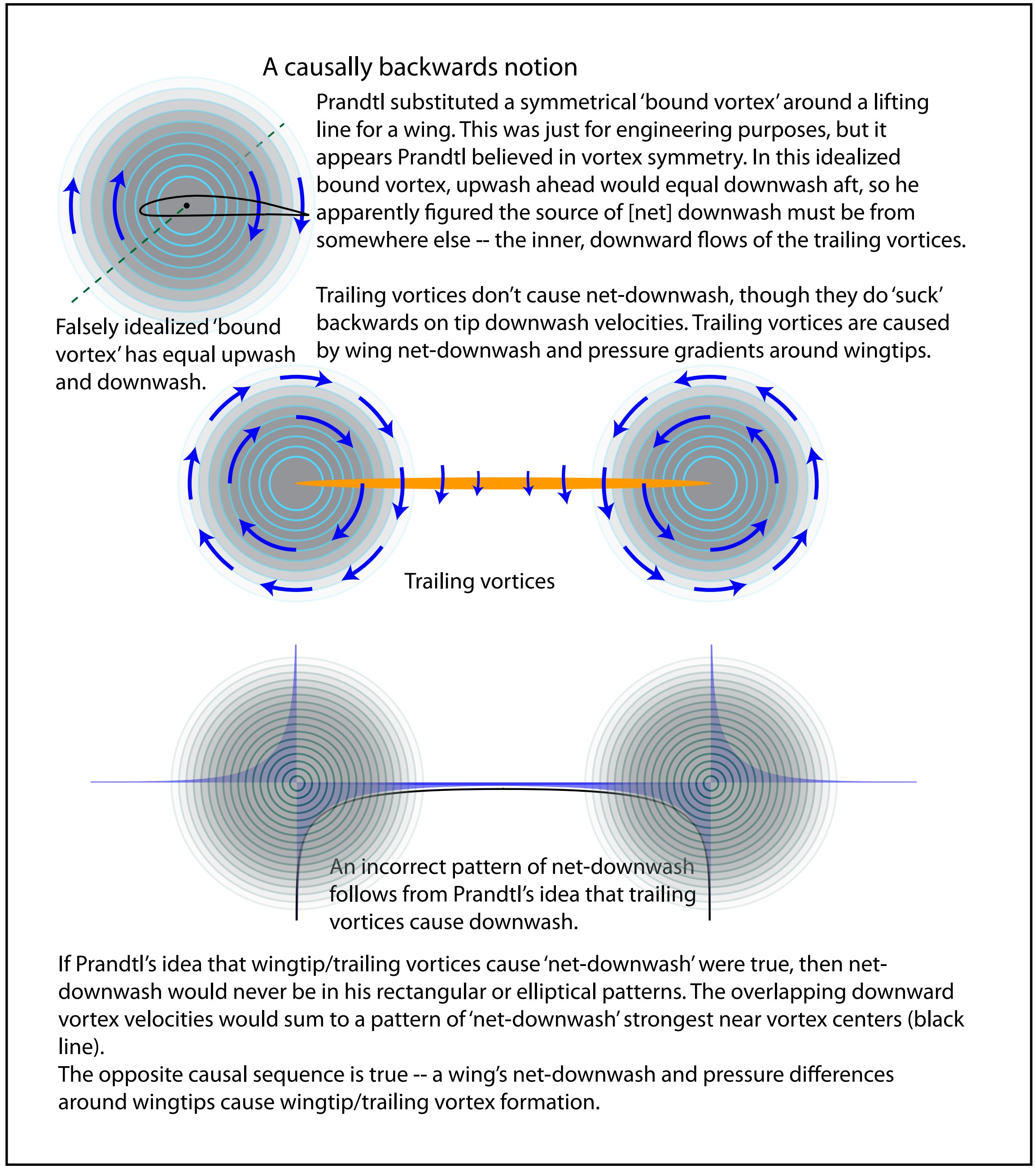


Figure 11: Prandtl falsely visualized the 'bound vortex' as symmetrical, and therefore imparting no downwash. He then (falsely) concluded that rotational velocities of the trailing vortices must create (net) downwash. He apparently ignored that this would lead to unrealistic wake downwash patterns, sticking with his 'rectangular' downwash pattern for elliptical spanloaded wings, probably moderately accurate.

in the trailing vortex drag back on the wingtip.

Equivalently, along each streamline spiraling up around the wingtip air is accelerated up, centripetally (in toward the center of the spiral), and back. The strongest accelerations are near the center of the forming wingtip vortex. For elliptical wingtips this strongest acceleration is at or just inboard of the wingtip. For BSLD wingtips the vortex center is further in. Pressure is used up accelerating air along streamlines. The poor pressure energy recovery near wingtips means this process is not completely reversed. These lowered pressures persist as the low-pressure center of the wingtip vortex.

The centripetal (x-z) acceleration around the wingtips makes the rotational velocities that are the trailing vortex and that further centrifuge the low pressures at the center of the trailing vortex.

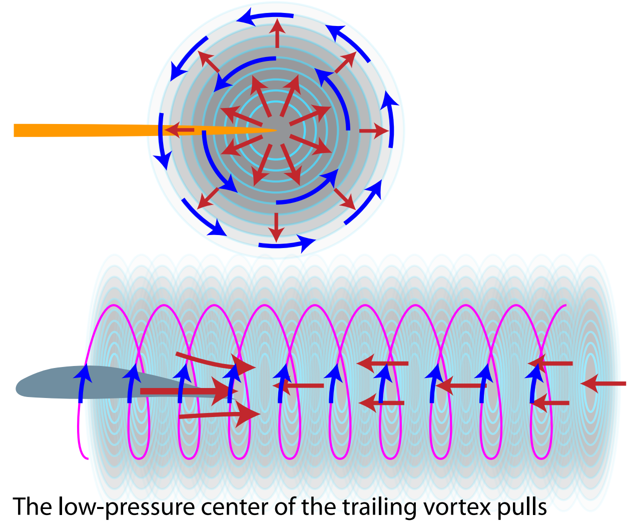
Vortex rotational velocities are also reinforced by the net-downwash pattern of the wing. An elliptical lift distribution wing's approximately rectangular pattern of net-downwash makes a powerful addition to the rotational momentum of the trailing vortex, as does the strong pressure gradient around its wingtip.

A BSLD wing's transition from central downwash to wingtip vortex upwash mixed downwash momentums make a more complex and softer influence on trailing vortex formation. Inboard of the crossover point the downwash momentums are strong and reinforce trailing vortex rotation. Outboard of the crossover point downwash momentums are weaker but fight vortex rotation. So the downwash momentums of the BSLD wing help to make its trailing vortex more diffuse. In combination with a more diffuse pressure gradient around wingtips, the resulting BSLD trailing vortices are broader, more diffuse, and have lower rotational velocities and weaker centrifuging near their centers. That means higher-pressure centers for less conflict with pressure energy recovery and less vortex drag than for elliptical wings of similar lift and root bending moment.

Again it should be emphasized that wingtip vortices are being formed by asymmetrical forces and momentums and only approach symmetry well behind the wing, as trailing vortices, at about the time they break up into the unevenness one observes in the aft part of contrails.

See Figure 12

Rotational velocities of the trailing vortex centrifuge its low-pressure center. Centrifugal forces are in red.



The low-pressure center of the trailing vortex pulls back on the wingtip and the air passing over and under the wingtip. Accelerating these flows destroys pressure energy recovery, a second reason the air behind wingtips is of low pressure. The difference between higher pressures ahead and lowered pressures aft is trailing vortex pressure drag. The low-pressure center of the trailing vortex also pulls forward on wake air.

Figure 12: Trailing vortex pressure drag.

The persistent false notion that wings gain lift only from downwash, rather than from Lanchester's reversal of upwash to downwash momentums

Aerodynamic misinterpretations persist. Similarly to how the false notion of 'longer path/equal transit times' was perpetuated by the misBernouligans through most of a century, there are others. One was carried forward by almost everyone. It is re-perpetuated in Robert T. Jones otherwise excellent *Wing Theory* (1990). It's the idea that lift comes only from downwash.

In 1894, 1897, and 1907, with his wave theory of lift, Frederick W. Lanchester had correctly asserted that lift comes from the reversal of upwash momentums ahead to somewhat greater downwash momentums aft.

Oddly, Jones, who champions Lanchester, had a partial grasp on Lanchester's correct explanation of lift. He even includes an extremely rare mention of Lanchester's theory of wave lift! (Which predated Lanchester's conceptual development of 'circulation lift.') In *Wing Theory* Jones writes,

> Recall that the lifting wing in two-dimensional flow does not require a continuous supply of energy to maintain its course if its speed is subsonic. The wing rides on a kind of wave having fore and aft symmetry, with upwash ahead and downwash behind. – Robert T. Jones, *Wing Theory*

That's close, if only true in a universe without turbulence. Even inviscid 2D wing polars show drag as the result of turbulence, 'bubble' formation (partial flow detachment), and stall. Thus even infinite wings require energy input to keep going.

But then Jones slips back into a conventional misunderstanding.

> The fact that the wing derives its lift by imparting downward momentum to the air… We can then think of the wing as encountering a circular jet of air with diameter equal to the span of the wing and as deflecting this jet downward.

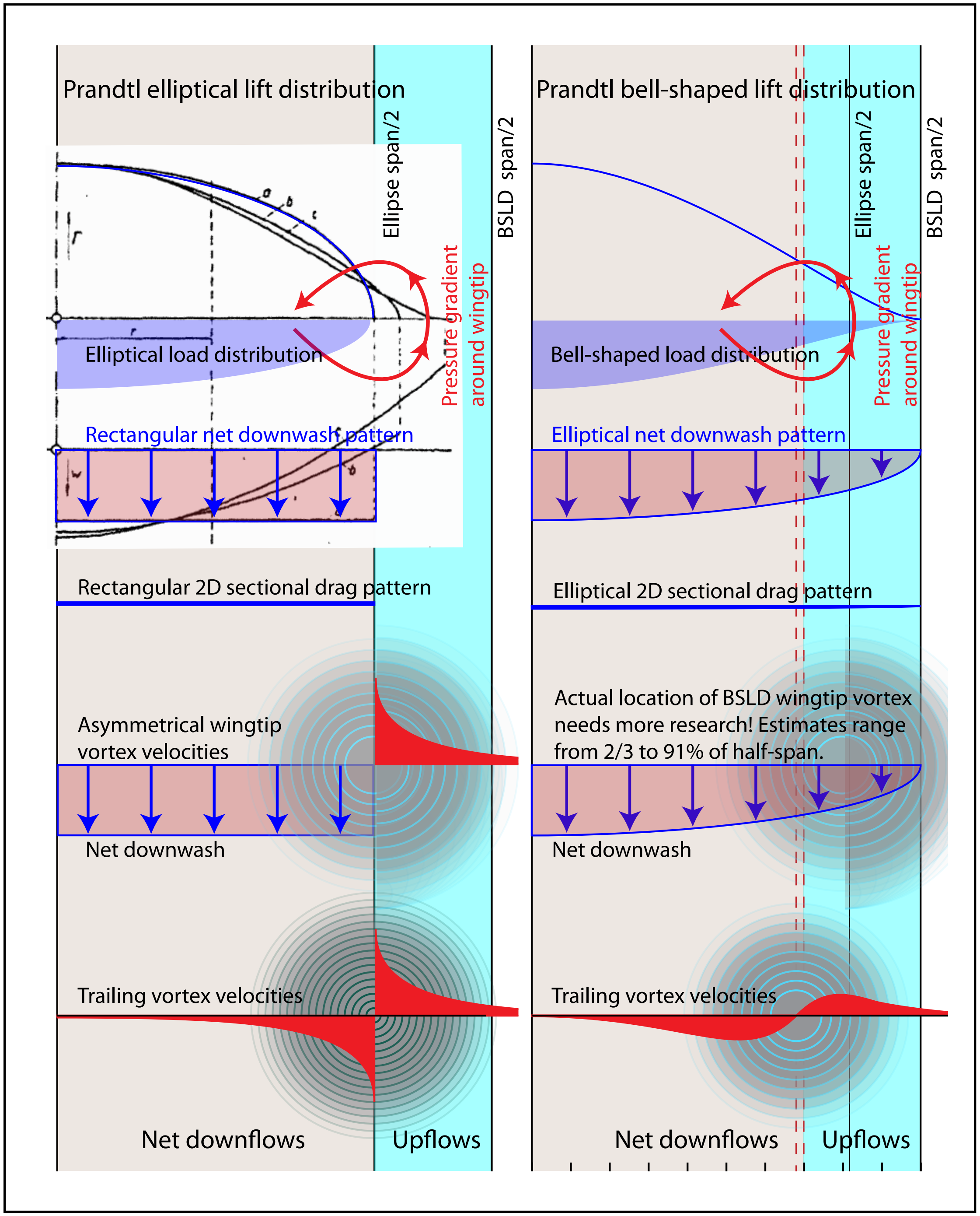
That's a scoop notion combined with the false idea that the momentum of horizontally flowing air 'deflected' downward is all that makes lift, rather than Lanchester's sum of the reversal of upwash to downwash momentums. It's the notion that wings stay up only by throwing air down. And in some interpretations this false notion of 'downwash' is plopped right into the center of Prandtl's analysis of BSLD wings. Referring to Prandtl's 1932 paper, Jones writes,

> This problem was considered many years ago by Prandtl. Prandtl suggested that the integrated or averaged bending moments along the span be used as a constraint… Thus for minimum drag with limited bending moment and given lift, the downwash should have a parabolic distribution. The span load distribution corresponding to this downwash can be obtained…

So: Whenever you see the diagrams of rectangular downwash for elliptical wings or parabolic downwash for BSLD wings, interpret the vaguely labeled 'downwash' as 'net downwash.' Also, note that 'parabolic downwash' is what lift forces do to air before the wingtip vortex bends that air upwards.

A more detailed diagrammatical summary. Adding the forces.

The following two diagrams sequentially trace how ELD wings and BSLD wings create the wingtip vortices, trailing vortices, trailing vortex pressure drag profiles, and the effect on drag reduction or thrust at BSLD wingtips. Not to scale.



For a BSLD wing, the vortex center is inboard of the crossover point. If there is a region of actual wingtip thrust it starts outboard of the crossover point. Even for drag reduction from a winglet riding in vortex upwash, drag reduction will start where wing airfoil section's L/D ratio makes an angle shallower that vortex upwash. That also will happen outboard of the crossover point, since near the crossover point upflow angles approach zero.

The bottom line is that portions of wingtips flying in vortex upwash may gain a bit of thrust if their Cl/Cd (L/D) glide angle is greater than the angle of vortex upwash. That thrust will at least make drag reduction by fighting trailing vortex pressure drag. Whether one can get an actual push out there isn't so important, but if so, that happens only when thrust is greater than vortex drag.

See Figures 13a and 13b

Figure 13a: From load distributions to trailing vortex velocities

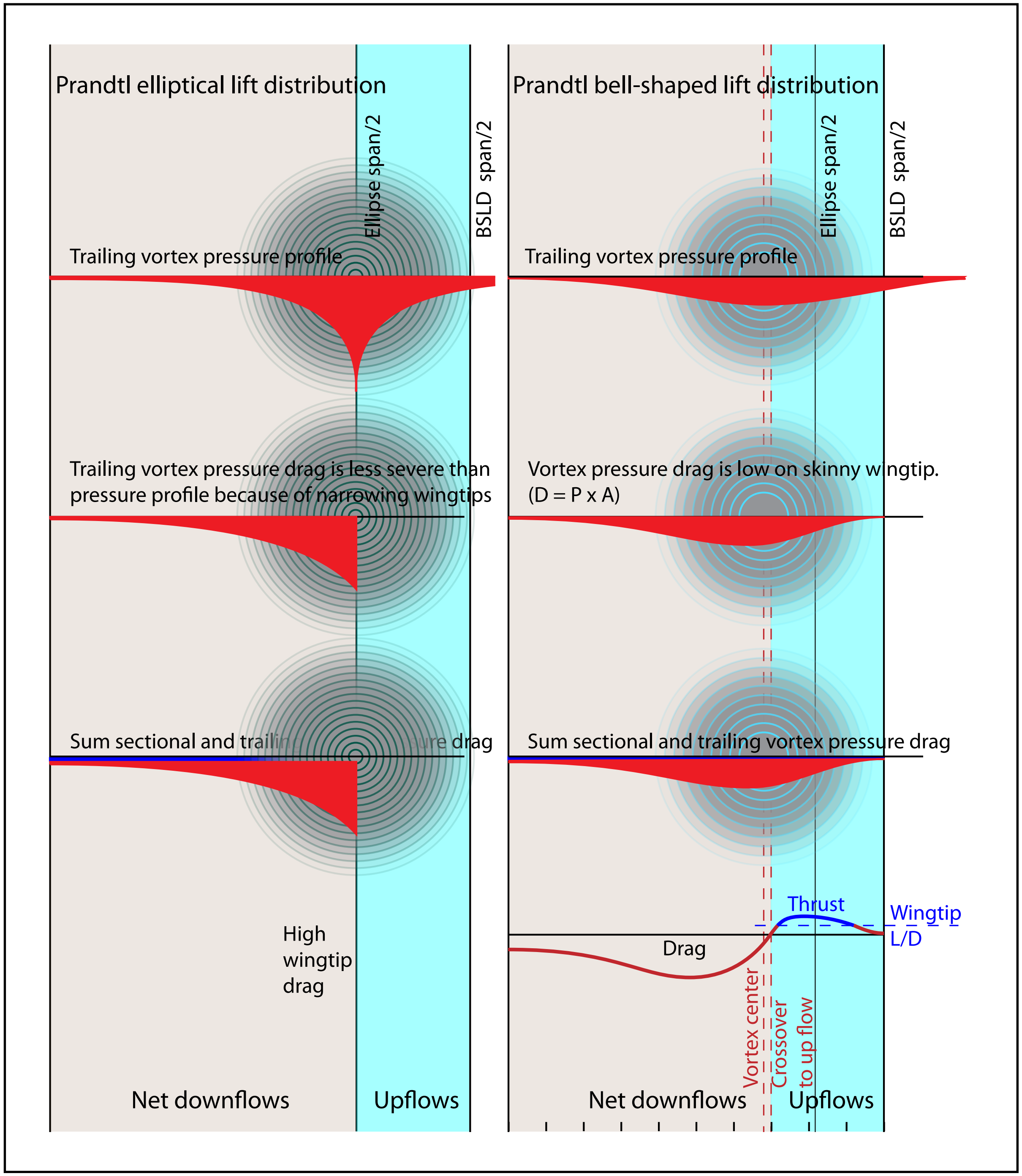


Figure 13b: From trailing vortex pressure profiles to BSLD wingtip drag reduction.

ELD-BSLD compromises

A page from Bill Kuhlman's five-part "Twist Distributions for Swept Wings" summarizes the concept that at least part of the benefits of a BSLD wing can be achieved with a more tapered lift distribution than elliptical.

See Figure 14

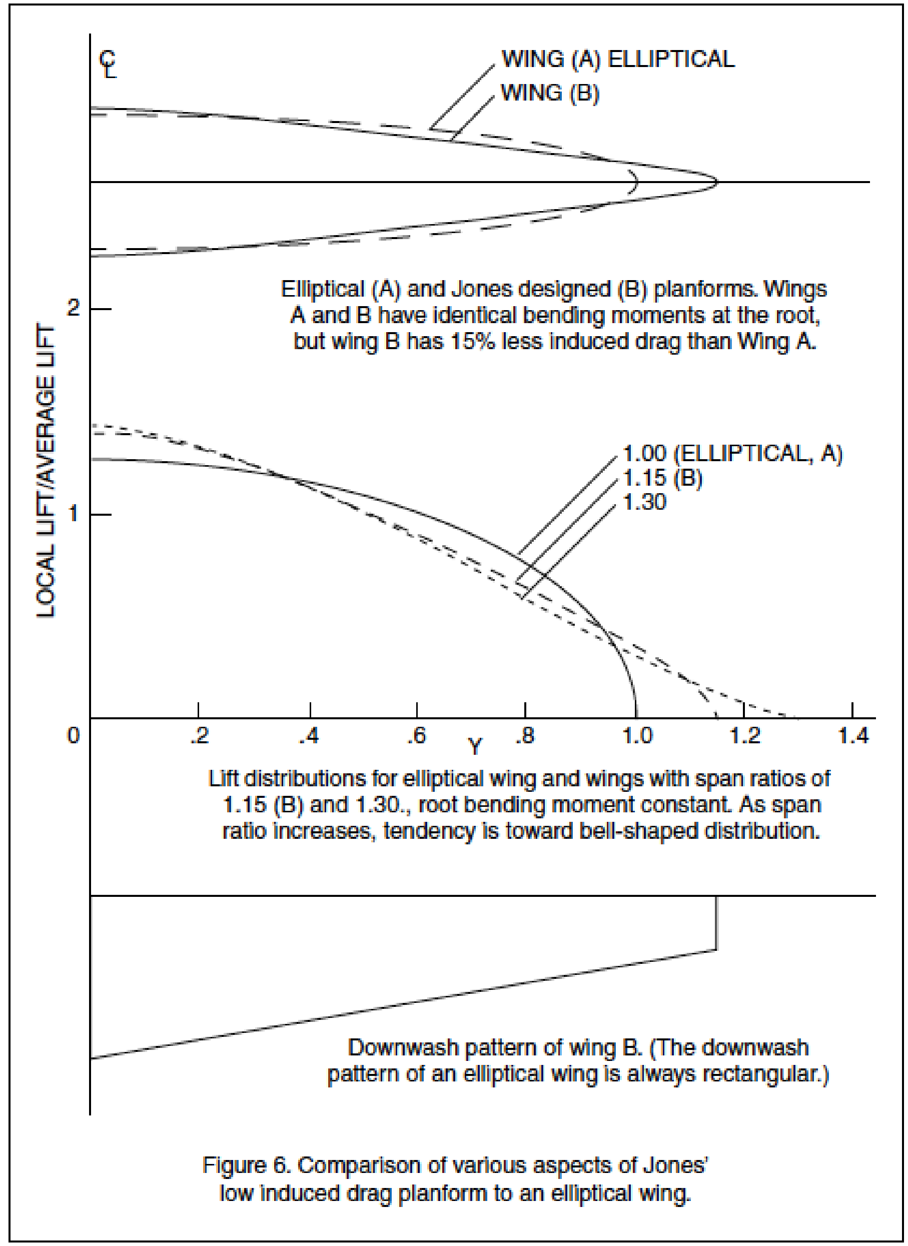


Figure 14: Jones low induced drag wing planform is a compromise between ELD and BSLD wings.[vi vii viii]

Proverse roll-yaw coupling.

Flying the undersides of shifting lift/drag curves with winglets in vortex upwash.
The effects of roll-control surface deflections on unequal trailing vortex drag.

Dragerons and thrusterons.

Adverse roll-yaw coupling

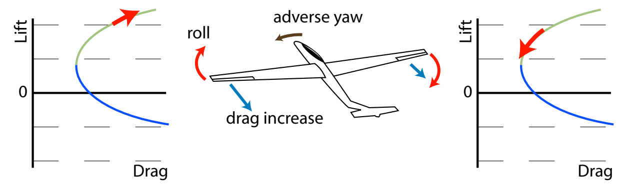
The problem: In most airplanes and model airplanes when aileron deflections roll the plane to the right the nose *usually* (with exceptions) yaws left. Or visa versa. That’s adverse roll-yaw coupling. It’s generally present even at cruise speeds, but it’s strongest at times of high coefficient of lift, at a high angle of attack, approaching stall. That happens most often in high G maneuvers or when a plane is near its slowest speed. For example, when a plane loses power shortly after takeoff pilots sometimes try to turn back to the runway while gliding at near-stall angles of attack (AoA). That combination of maneuvering when adverse yaw is strongest threatens spin without sufficient altitude for recovery.

See Figures 15 and 16

Piloting is easiest when airplanes are well behaved and do what a pilot wants with minimal correction. To make coordinated turns pilots generally correct adverse roll-yaw coupling with rudder deflection. Full-scale pilots use the rudder pedals. Model pilots use the left stick. Or they program in aileron-rudder mix, generally with aileron ‘differential.’ Model flying wing pilots trust to fins. That’s technically sloppy, but Zagis get by just fine. It’s possible to do better. There is a long history of designing airplanes with neutral or even ‘proverse’ roll-yaw coupling. However, there are always tradeoffs.

And for many, the main benefit of looking at BSLD and proverse roll-yaw forces will be greater understanding of what happens around wings.

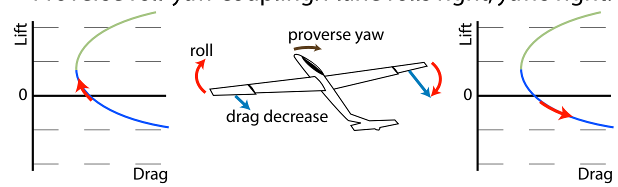
Adverse roll-yaw coupling. Plane rolls right, yaws left.
Coordinated turn requires rudder correction



Left wing: In the adverse part of the L/D curve, drag increases with lift

Right wing: In the adverse part of the L/D curve, drag decreases as lift decreases

Proverse roll-yaw coupling. Plane rolls right, yaws right.



Left wing: In the proverse part of the L/D curve, drag decreases as lift increases

Right wing: In the proverse part of the L/D curve, drag increases as lift decreases

Note: The above simplied lift/drag curves work for AoA roll-control devices, e.g. ‘tiperons.’ Cl/Cd curves for aileron deflections are more complex. Vortex influences add a third level of complexity.

Figure 15: Roll-yaw coupling

Even though engineering is beyond this article, it contains hints for building a proverse roll-yaw coupling engineering methodology via adjusted Cl/Cd curves. And we'll get to practical examples of what should work and what won't, and problems with a couple historical approaches. We'll look at the Horten brothers' proverse approach, the high adverse roll-yaw coupling of the Wright Flyers, implications for elliptical and bell-shaped lift distributions, and an imaginary Piper Cub equipped with tiperons – rotating wingtips.

Please be aware that structural and aerodynamic benefits of BSLD, proverse roll-yaw coupling, induced wingtip thrust, and flying wings are separate subjects, though usually interrelated. It's true that most solutions for proverse yaw will have a lift distribution closer to bell-shaped than elliptical, but in some optimums lift at wingtips may even be negative. And there are proverse roll-yaw solutions for standard-planform aircraft and canards as well as for flying wings.

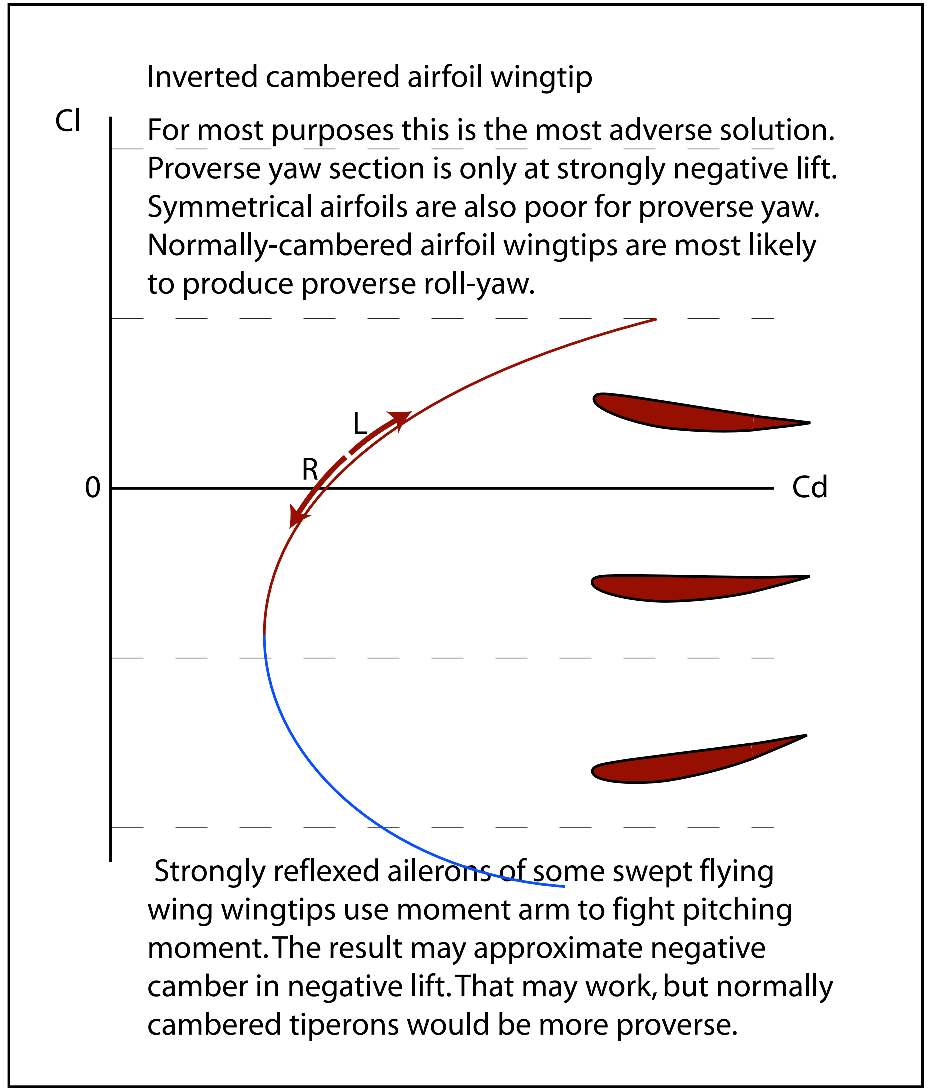


Figure 16: Inverted cambered wingtips generally make adverse roll-yaw coupling forces.

Pre-summary:

The easy but partial argument: Within the rising air outboard of the vortex center and even a bit outboard of the 'crossover point,' by changing angle of attack or by aileron deflection, a lightly loaded wingtip may gain thrust in the way a glider gains thrust within rising air. A component of the lift force may be in the direction of flight -- thrust. For a bit of wing section to contribute thrust the air must be rising at an angle steeper than the section's actual glide ratio, which will be worse than its 2D sectional Cl/Cd because of wingtip pressure difference losses. And not all such thrust will be greater than trailing vortex pressure drag, but that doesn't matter for proverse roll-yaw coupling. What matters is that on left and right aileron or tiperon deflections, left and right changes in thrust and (adverse) changes in trailing vortex pressure drag add up such that a right roll is accompanied by right yaw.

With wingtips in significant vortex upwash: For the left wingtip, a roll to the right is accompanied by the left wing pushing forward, for proverse roll-yaw coupling. The right wingtip, with aileron deflected upwards, may decrease thrust as it drops, again for proverse roll-yaw coupling.

The more complete argument: All that is required for proverse roll-yaw coupling is that sectional airfoils operate in negatively sloped portions of their adjusted lift/drag curves, where lift and drag move in opposite directions. That usually means proverse roll-yaw forces are generated from airfoil sections in fairly low or negative lift, in relation to local flows.

Proverse roll-yaw coupling analysis requires adding a number of effects. Flying winglets in vortex upwash shifts their Cl/Cd (lift/drag) curves up (added lift) and to the left (reduced drag). Wingtip vortex formation lessens pressure differences between upper and lower wingtip surfaces, shifting Cl/Cd curves down (lessening lift). Trailing vortex pressure drag and airfoil drag shift the curve back to the right (increased drag). The summed result is that tiperons or even lightly loaded wingtips with ailerons can often operate in the area of their adjusted Cl/Cd curves, below the 'drag bucket,' where an increase in lift makes a decrease in drag. That makes a coordinated turn, a proverse roll-yaw coupling, without the use of a rudder.

But even a standard cambered elliptical wing, exerting no lift while briefly in a ballistic (zero gravity) parabolic trajectory, will generally be operating in a negatively sloped area of its lift/drag curve, and will respond proversely to aileron deflections. In contrast, at a wing's highest Cls, adverse roll-yaw forces are strongest.

As we'll see, tiperons will generally be more proverse than ailerons. That's partly because tiperons can maintain proverse angles of attack regardless of the incidence of the main wing. A morphing tiperon would be able to set variable angles of attack along its span, to optimize drag reduction or thrust within the different slopes of vortex upwash. The morphing could be via aileron.

Summary of the wingtip vortex upwash in which a lightly loaded wingtip may fly

As said, a winglet, whether vertical or horizontal, can catch a bit of thrust if it extends into the upward swirl of flows around a wingtip. That seems simple enough. It isn't. The location and profile of the upward flows is a result of several forces. For a BSLD wingtip the downward force on air from lift is small, and too weak to overcome the upward forces from pressure differences that make the upward wingtip vortex swirl. The resulting flows are from a balance of lift forces and wingtip vortex forces. Since the wingtip vortex center exerts no downward or upward force, it is only further out that wingtip vortex upward forces exceed wing lift downward forces on air. Thus the vortex center is inboard of the 'crossover point.'

All wings have to fight the downward 'induced angle of attack' (caused by lift forces on air). But outboard of the vortex center this downward angle of flows is lessened even before the crossover point. So outboard of the vortex center the upward wingtip vortex forces lower drag, perhaps transitioning further out to actual thrust.

An additional paradox is that ‘net-downwash’ for a BSLD wing is generally pictured as elliptical, while we know that outboard of the ‘crossover point’ flows go up. What gives? Probably the elliptical pattern of net-downwash ignores vortex upwash.

Complexity

Back when I posted the beginnings of this article to *Nurflugel* I had an idea, not necessarily new but new to me, that toward lower drag or even thrust. And every deflection of roll control surfaces changes lift distribution unequally, left and right, which changes the strength, spread, and spanwise location of trailing vortices and associated drag, again, unequal left to right, making adverse roll-yaw coupled forces only quantifiable with a 3D analysis. Since a BSLD wing can have proverse roll-yaw coupling, its proverse airfoil forces exceed these adverse trailing vortex pressure drag forces.

of lift/drag polars, and the discussion of how the conflict of BSLD downward lift forces on air with upward wingtip vortex forces on air determines the ‘crossover point’ and the ‘induced’ angles of flows outboard of the wingtip vortex center.

Proversely flying the lift/drag polar ‘drag buckets’ and their shifts with AoA and camber changes and with their span location in vortex up-or-down flows

The definitive tools for conceptually analyzing roll-yaw coupling are vortex-

In aerodynamics a polar diagram graphs two interdependent variables.

proverse roll-yaw forces are from areas of an airfoil’s (2D) lift/drag curve where as lift increased drag decreased, making a coordinated turn. (I think the formatting of my rather crude graphs worked when Yahoo sent them to members as emails, but not on the site. Oh well.) Comments, corrections, and time have helped.

But things are not as simple as that partially scrambled starting point. Each truth roused additional complexity. Ailerons make more complex shifts of lift/drag curves than do simple angle of attack changes. Wingtips fly in vortex upwash, usually shifting curves

This is a conceptual article. I expect the true experts to publish a comprehensive and quantitative article in the not-too-distant future. Do I have something that will help? Perhaps, or perhaps what I write here will be old hat. Still, it’s my observation that, within aerodynamics, computational fluid dynamics (CFD) and wind tunnel data produce excellent engineering even while concept lags. So perhaps I can make a contribution, or at least stimulate the discussion.

Two areas I haven’t heard used by others for roll-yaw coupling analysis are the use

shifted lift/drag polar diagrams. These are potentially also good tools for design, though that would require building a reliable engineering methodology. There are of course other approaches, from trial and error to CFD, excellent for results but usually poor for comprehension. The goal is to leave readers with understanding and concept sufficient for gut-level guidance.

It’s inadequate to use standard lift/drag polar diagrams to analyze roll-yaw coupling. That’s because standard ‘polars’ show the lift and drag of a wing section at various angles of attack or aileron deflection *in relation to local flows, and generally before wingtip pressure-difference losses*. But subsonic flows are always either tilted down (induced angle of attack) or up (wingtip vortex upwash) within the 3D forces of lift. Thus L/D polars don't initially show lift and drag *in relation to flight path*, which is what counts. We'll adjust L/D polars for induced angle of attack and wingtip vortex upwash at different parts of various wings' spans.

These polars adjusted for vortex upflows or downflows then allow a consistent rule: Roll control deflections of wing sections flying in positively sloped areas of the vortex-shifted L/D curve make adverse yaw. That's where an increase in lift makes an increase in drag. Control deflections of wing sections flying in negatively sloped areas of the vortex-shifted L/D curve make proverse yaw—where an increase in lift makes a decrease in drag. The curve is king.

Portions of ELD wings with roll-control surfaces fly the in local down-flows (induced AoA, net downwash, or vortex sink), which makes for adverse roll-yaw coupling. Ailerons or tiperons on BSLD wingtips or other lightly loaded wingtip extensions fly in wingtip upwash. There they are more likely to exert proverse roll-yaw coupling forces.

Polar diagrams: In aerodynamics a polar diagram graphs two interdependent variables. That's in contrast to simpler mathematical functions with an independent variable unaffected by a dependent variable. For example, when Galileo dropped a weight from the leaning tower of Pisa the changing velocity of the weight over time didn't affect time. Disambiguation: In sailing, 'polar diagram' just means 'circular,' a graph of headings-in-relation-to-the-wind (the independent variable) versus speed (the dependent variable.) Which is a poor use of the data and bad third-grade arithmetic, but that's another story.

Angle of attack devices: A tiperon is a wingtip that pivots around its quarter chord line. Wingeron wings rotate in opposite directions for roll control, with pitch controlled by an elevator. Pitcheron wings also rotate in opposite directions for roll control, but collectively change angle of incidence (decolage) in relation to the chord line of a fixed horizontal stabilizer. They control pitch with variable longitudinal dihedral or decalage. Wing-warping changes AoA without changing camber, supposedly. (The upper fabric of the 1910 Wright Model B wing was secured only at leading and trailing edges. In flight it would belly up, increasing camber![ix]) Wing-warping was used on the Wright flyers, the Bleriot XI (1909), the Fokker Eindecker monoplane (1915), and others till about 1915. After 1915 ailerons predominated, mainly because they allowed stronger wing structure and thus better roll control. *AoA changes shift L/D along the lift/drag polar curves*.

Pure camber changing devices are commercially rare or nonexistent. Perhaps someone working with wing morphing has built one. *Camber changes move the L/D curve nearly vertically*.

Camber/AoA changing devices include ailerons, flaperons, and elevons. As an aileron is deflected down it increases camber and AoA. If we hold the incidence of the airplane constant we can graph the L/D changes with aileron deflections. *Deflections of ailerons move L/D by a combination of the near-vertical camber-change shifts of the L/D curve and the AoA shifts along the L/D curve.*

Drag buckets. Flying wingtips with roll-control surfaces beneath the wingtip-vortex-adjusted drag bucket for proverse roll-yaw coupling: The nearly vertical left portion of a lift/drag polar is the drag bucket. It's where drag is lowest. Most airplanes are designed to cruise near the top of their drag bucket, ideally where the slope of Cl/Cd is steepest, for best L/D and fuel efficiency at that cruise speed. The drag bucket for an entire airplane is in relation to flight path and is not the same as drag buckets of wing sections in relation to local flows (given by standard polars), which need to be adjusted in relation to flight path, which is what counts.

To make proverse roll-yaw coupling forces a wing section with roll-control surfaces must fly beneath the drag bucket of the appropriate, local-flow-angle-adjusted Cl/Cd curve.

CFD for design. Three conceptual approaches to achieving proverse yaw.

There is one design approach and three conceptual approaches to looking at roll-yaw coupling. The definitive design method is via CFD (computational fluid dynamics) 3D analysis. That's beyond the scope of this article. It's superb for design, great for verification of conceptual analyses, and doesn't necessarily offer good explanations of what is going on.

Conceptually there are three required approaches to understanding roll-yaw coupling:

• First is gaining thrust or reducing drag by flying a lightly-loaded wingtip with control surfaces in vortex upwash. When equipped with ailerons the differential effects of left and right deflections on thrust or drag can make proverse yaw forces. BSLD wings have such lightly loaded wingtips as well as structural and drag advantages; these topics are the focus of most discussions.

• Second is conceptually adjusting 2D airfoil Cl/Cd polar diagrams, to see where lift and drag move in opposite directions upon roll-control surface deflection, for coordinated turns.

• Third is adverse yaw forces from changes in trailing vortex pressure drag caused by aileron deflection. Roll-control surface deflections unequally affect lift distribution; lift distribution changes affect the location and strength of wingtip vortices. Wingtip vortices affect the location and pressure profiles of trailing vortices and thus the induced or vortex drag profile of the wing. *For positively lifting wingtips with ailerons, trailing vortex pressure-drag is always an adverse yaw force!* But for BSLD wings the vortex center is probably sufficiently inboard that this third effect is not the dominant yaw producing force.

So trailing vortex formation is a function of lift distribution. At one end of a continuum of lift distributions, if Cl is zero across a wing's span it doesn't produce a vortex. In contrast, if aileron deflection increases winglet lift till lift distribution approximates elliptical the vortex center will move outward to near the tip, eliminating the possibility of the tip riding in vortex upwash. Aileron deflection then exerts the usual adverse roll-yaw coupling typical of ELD wings.

In various planforms and lift distributions these three effects can reinforce or fight each other. We'll make sense of it all.

Thrusterons and dragerons

There are two interrelated approaches to design for proverse roll-yaw coupling. Each is limited by the adverse vortex-drag yaw effects of aileron deflection. The first is to extend a carefully designed lightly-loaded roll-controlling bit of wing into the rising flows of the wingtip vortex. It will either be a tiperon or will be equipped with ailerons. *Such a wingtip can act like a glider in rising air.* On deflection to slight positive lift (in relation to local vortex upflows) it can provide thrust that can help yaw the airplane in the direction of roll. The thrust may not be absolute – such thrust may not exceed vortex pressure-drag (which adversely increases with increasing lift). But that thrust will lower drag. We could call that the 'thrusteron' approach.

As the opposite wingtip lessens its lift it may increase drag, also creating proverse roll-yaw forces. We'll see the specific conditions where this works.

Even within wingtip vortex upwash a thrusteron must be lightly or negatively loaded to make proverse roll-yaw forces. If it is too heavily loaded it will operate in an adverse yaw area of its (shifted) lift drag curve, it will chase the crossover point further out toward the wingtip, and will create adverse trailing-vortex pressure-drag yaw forces.

Second, in regions without sufficient vortex upwash to make proverse yaw on aileron or AoA deflection: to create proverse yaw forces, portions of wings with control surfaces must operate in regions of their lift/drag polar curves where control input moves lift and drag in opposite directions. These proverse regions of the lift/drag curve are generally at low or negative coefficients of lift, in turn found at local low or negative angles of attack, for example, during low-or-negative G pushovers. High speeds may allow some airfoils to operate in a low-but-positive-lift proverse region of their Cl curves. Roll-control surfaces that change wing drags such that roll and yaw are coordinated could be called dragerons. (However, the term is taken. It refers to devices that increase drag to control yaw. Split ailerons are an example that also work as air brakes.)

The two effects can be combined in tiperons or in wingtips with ailerons operating in vortex upwash. There is a continuum from lowering drag to increasing thrust while increasing lift.

As mentioned, the effects of aileron deflection on vortex pressure drag are roll-yaw-adverse. They either make adverse roll-yaw coupling worse or partially fight proverse yaw forces. Because of vortex location, adverse roll-yaw vortex pressure-drag forces will be stronger for elliptical wings than for BSLD wings if each has ailerons near their tips.

See Figure 17

For tiperons the bottom line is the vortex-upwash-shifted lift/drag polar. For wingtips with ailerons the bottom line is the vortex-upwash-shifted aileron deflection Cl/Cd curves, that we'll look at later.

Thrusterons on a Cub

Imagine a short-takeoff-and-land (STOL) airplane, perhaps a Super Cub, flying slowly with enough altitude for safe recovery. Its pilot isn't using its ailerons or rudder. Instead it has 'tiperons' protruding outward from its wingtips. They have a three-foot chord, are five feet long, and sport a symmetrical airfoil to avoid pitching moment forces. They are mounted on shafts just ahead of their quarter-chord lines. The mechanical linkage is such that the pilot can rotate them a few degrees in opposite directions with left-right movements of the stick, but collectively they align with the local airflow. They aren't an optimum, but they work. Because the plane is mushing along there is steep vortex upwash outboard of its normal wingtips. The pilot tips their control stick to the right. The left tiperon increases

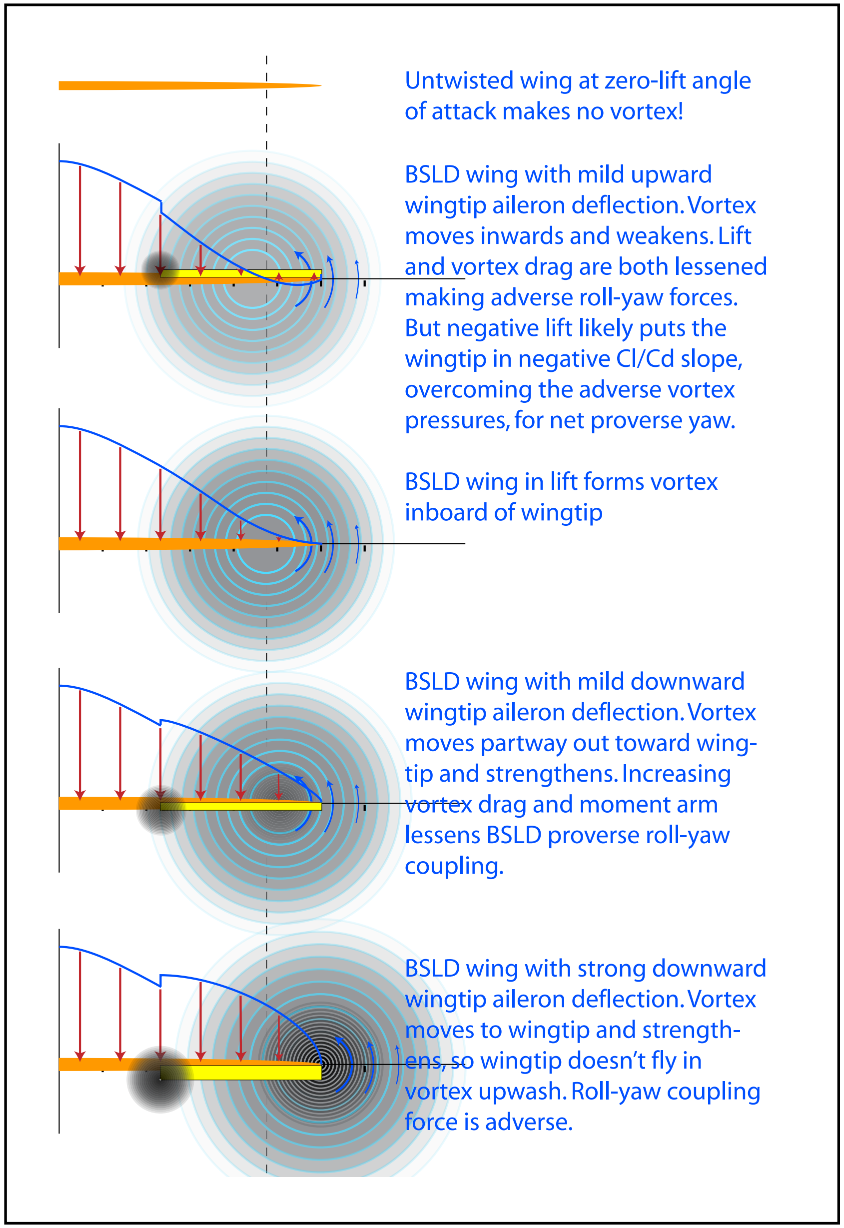


Figure 17: Adverse roll-yaw coupling effects of trailing vortex pressure drag.

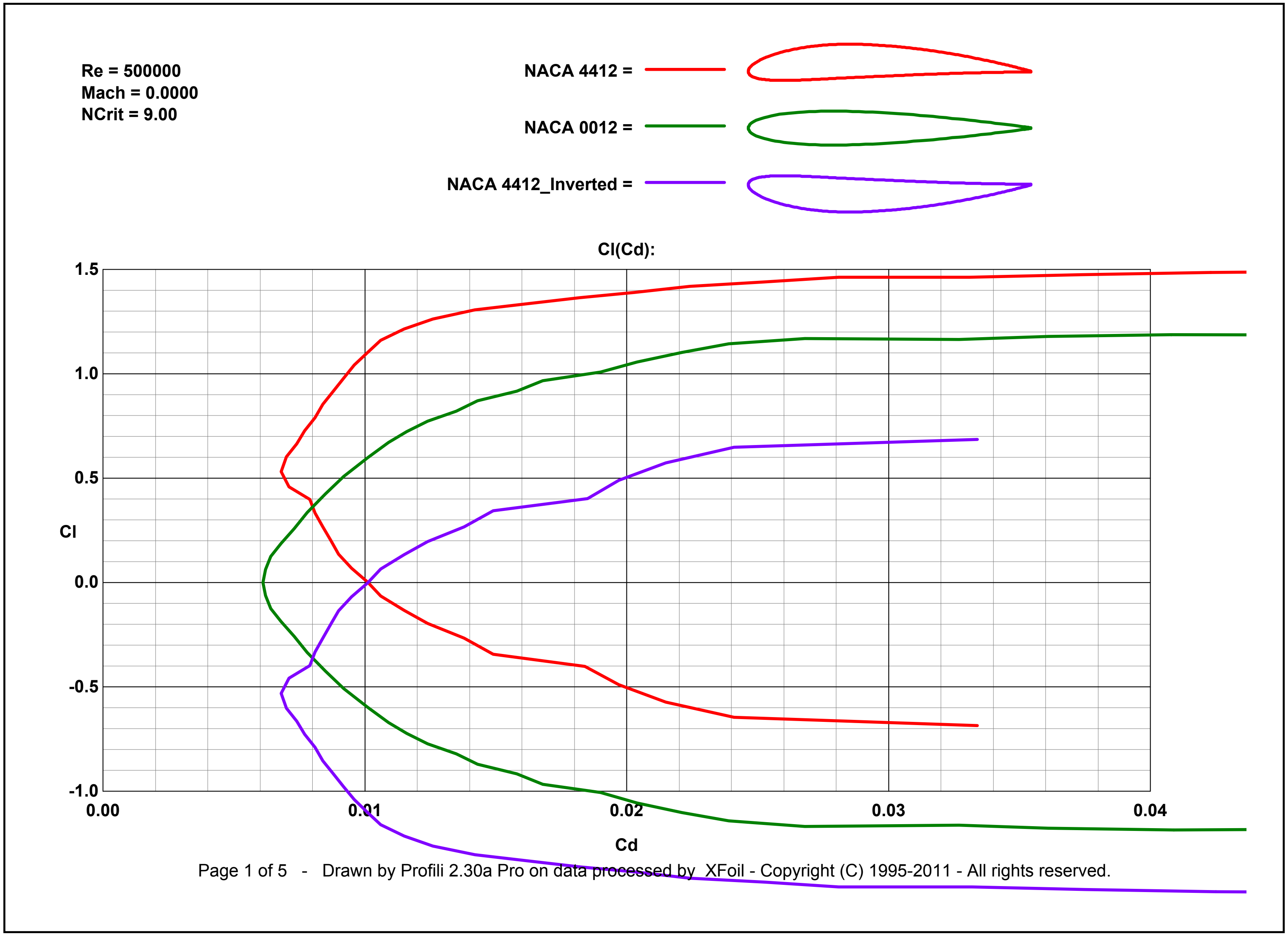


Figure 18: Camber shifts the Cl/Cd curves vertically. Profili plots by Adam Weston

its AoA relative to local upwash from zero to three degrees. Just like a glider in a thermal updraft it gains lift and thrust, rolling and yawing the plane to the right. The right tiperon hits a negative angle of attack relative to local up flows, for negative lift and increasing drag, also rolling and yawing the plane to the right.

Our pilot-designer has not achieved the energy or structural efficiency possible with BSLD wings. But with a small sacrifice of efficiency he has used the stronger upwash outboard of a standard elliptical or Hershey-bar wing to achieve stronger proverse roll-yaw coupling than would be expected from a true BSLD wing. Trade-offs.

The pilot improves on his design. He uses cambered airfoils for his tiperons, and adds trim tabs set so that in slow straight flight his tiperons maintain low lifting angles of attack relative to the vortex upwash. The tiperon winglets provide thrust, salvaging a bit of energy from wintip vortices. For cruise he gets fancy. At cruise speeds upwash outboard of wingtips is weaker and a bit too flat to gain much thrust. But he knows that at low positive angles of attack his cambered airfoils will still move roll and yaw in coordination. He builds trim tabs adjustable in flight and searches for optimums of efficiency and proverse roll-yaw coupling.

If the pilot operates his tiperons at a coefficient of lift similar to that of the rest of the wing they become merely a strongly lifting extension of the wing (good for short landings, but adverse). That moves the wingtip vortex outward so that the tiperons are no longer flying in vortex upwash. Then as he moves his tiperon stick left and right the lift and drag of each tiperon move in the same direction for standard adverse roll-yaw coupling. Thus the pilot has to use his rudder. Wingtips with control surfaces only produce proverse roll-yaw coupling when operated at fairly low coefficients of lift, and even that depends on the Cl/Cd curve of the airfoil.

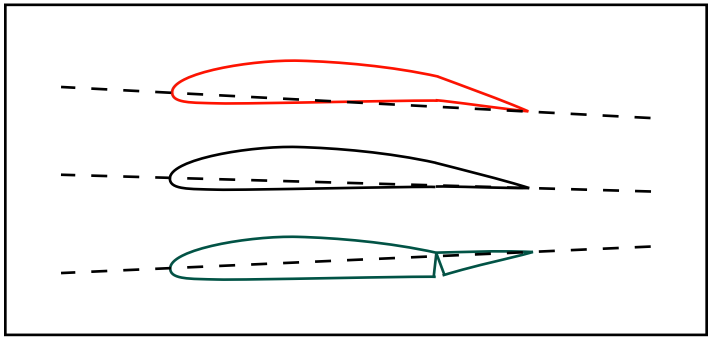


Figure 19: Aileron deflection changes both AoA and camber.

The factors

Whether roll-yaw coupling from control surface deflection is adverse, neutral, or proverse is determined by several factors plus their interactions.

These are:

1: The effects of aileron or tiperon deflection on wingtip/trailing vortex drag. This is always an adverse roll-yaw force, which must be overcome by proverse forces.

2: The effects of AoA (angle-of-attack) roll-control devices (tiperons, wingerons, and pitcherons, and AoA wing-warping). AoA devices *slide* L/D *along* the lift/drag curve. This is a two-dimensional, airfoil sectional analysis in which freestream velocities are assumed parallel to flight path. See figure 15

3: Camber change *shifts* the entire lift/drag curve nearly vertically. That’s critical information, though pure camber-changing devices aren’t in use.

See Figure 18.

4: The effects of camber-and-AoA-changing roll-control devices (ailerons, flaperons, elevons, and the Wright’s wing warping).

See Figures 19 and 20

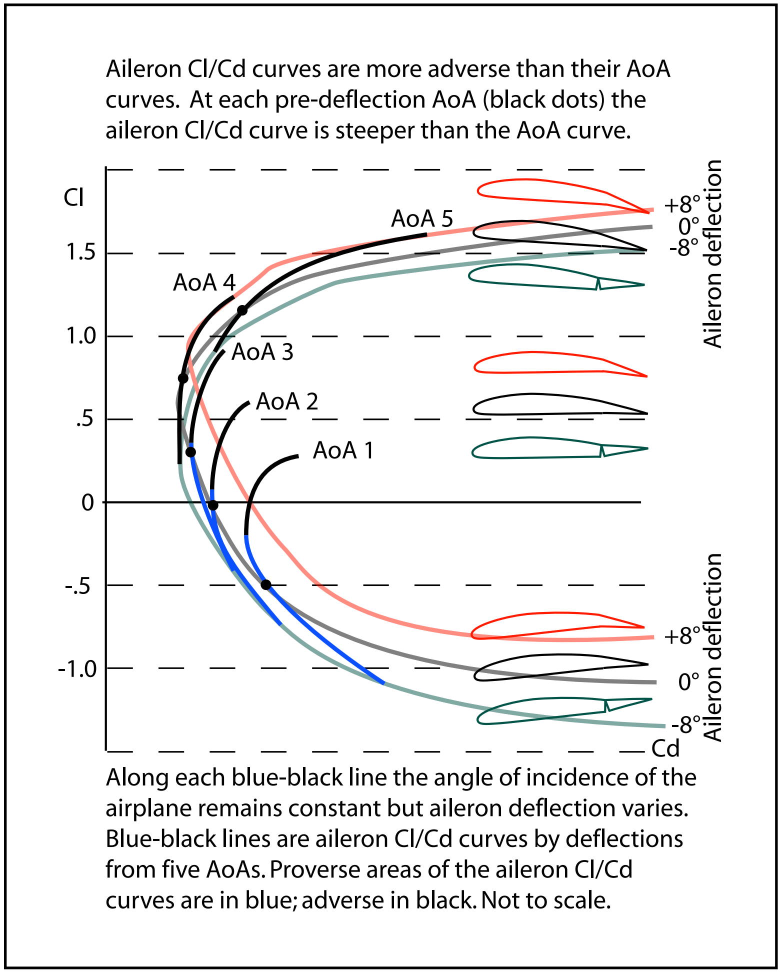


Figure 20: Aileron Cl/Cd curves are more adverse than tiperon (AoA) Cl/Cd curves. Cambered tiperons are probably the best choice for achieving proverse roll-yaw coupling.

5: Angles of attack – what part of the appropriate Cl/Cd curve the wingtips are at.

6: The location of roll-control devices within wingtip vortex upwash. Here our analysis becomes 3D. Generally for proverse yaw, wing segments with control surfaces are designed to fly in wingtip vortex upwash. Like little glider wings they gain thrust (or at least reduce drag) by riding in up-currents. For the L/D of the airplane in relation to freestream velocities (as opposed to local upwash velocities), this *shifts* the lift/drag curve up and to the left, toward lower drag or even negative drag, thrust.

See Figure 21 and 22.

7: The effects of *lift distribution* on location of wingtip vortex location, strength, and vortex upwash or downwash. Generally segments of wings with roll control surfaces must be lightly or negatively loaded to fly in wingtip vortex upwash; a strongly loaded segment will move wingtip vortex upwash outboard of itself. Hence lift distributions designed for proverse yaw usually (but not strictly or always) approximate a ‘bell shaped lift distribution’ (BSLD) rather than the more common elliptical lift distribution.

8: The effects of trailing vortex pressure drag on wingtip thrust or drag.

See Figure 23

9: The effects of roll-control deflections on lift distribution; wingtip and trailing vortex location and the strength; location, and pressure profile of trailing vortex drag. E.g. when an aileron is deflected down it increases lift, shifting the wingtip vortex outward.

10: Different airfoils have differently shaped lift/drag curves and will be better or worse for proverse roll-yaw control wingtips.

See Figures 24, 25 and 26

11: Other: Spanwise flows and flow attachment, etc., mostly ignored here.

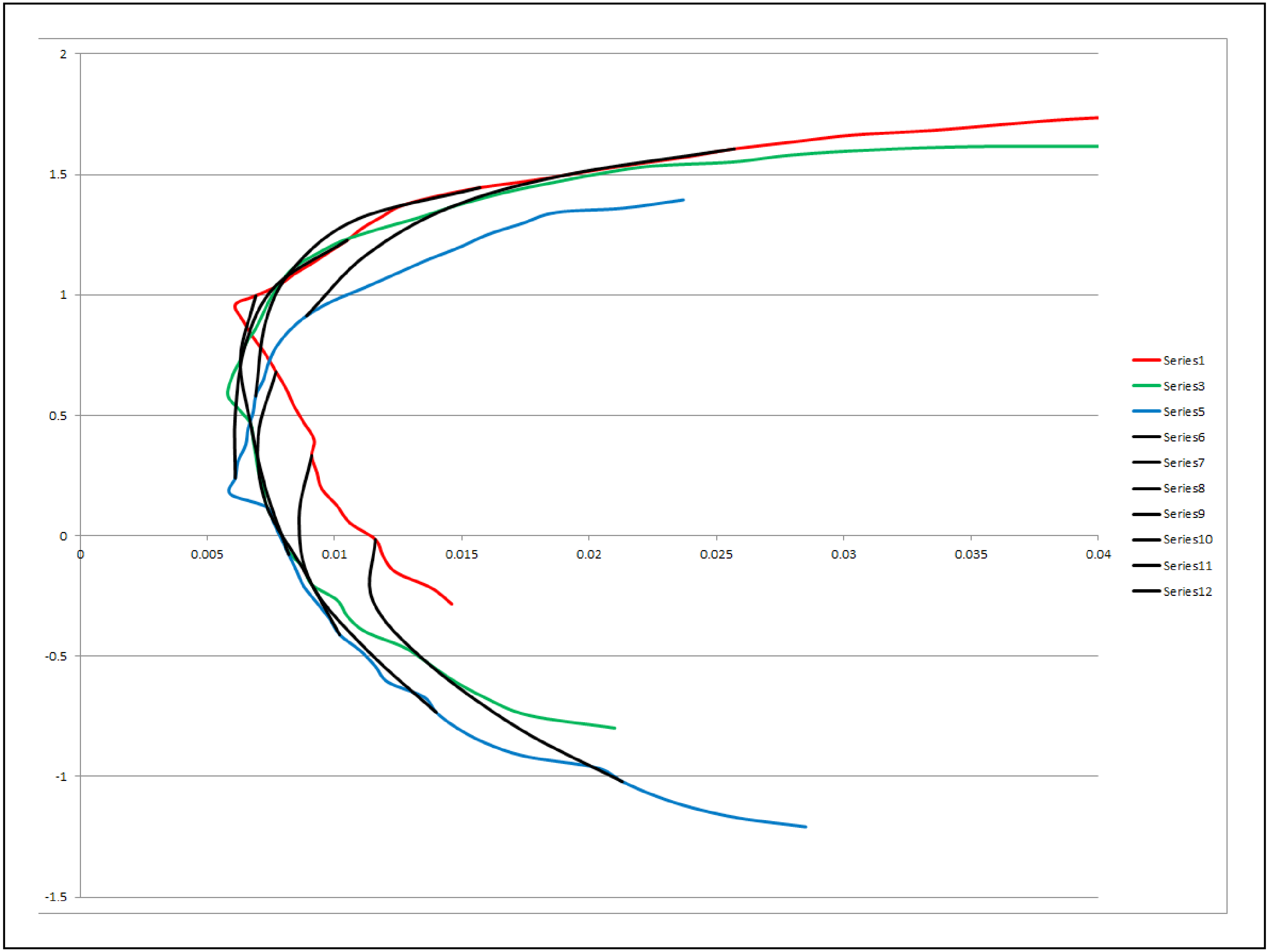
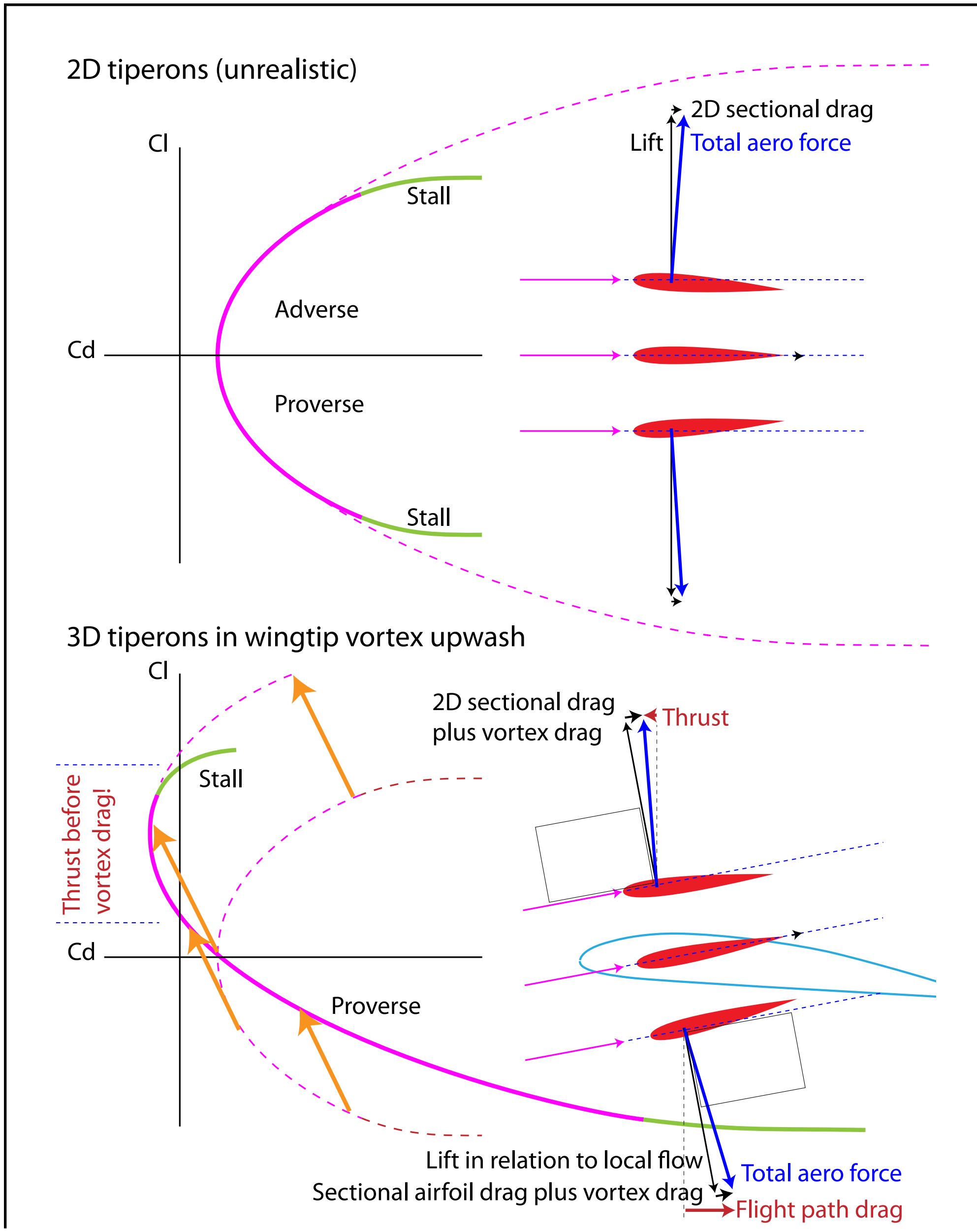


Figure 21: Aileron Cl/Cd curves (black) are only proverse at lower Cls than AoA Cl/Cd curves. Profili plot by Adam Weston.



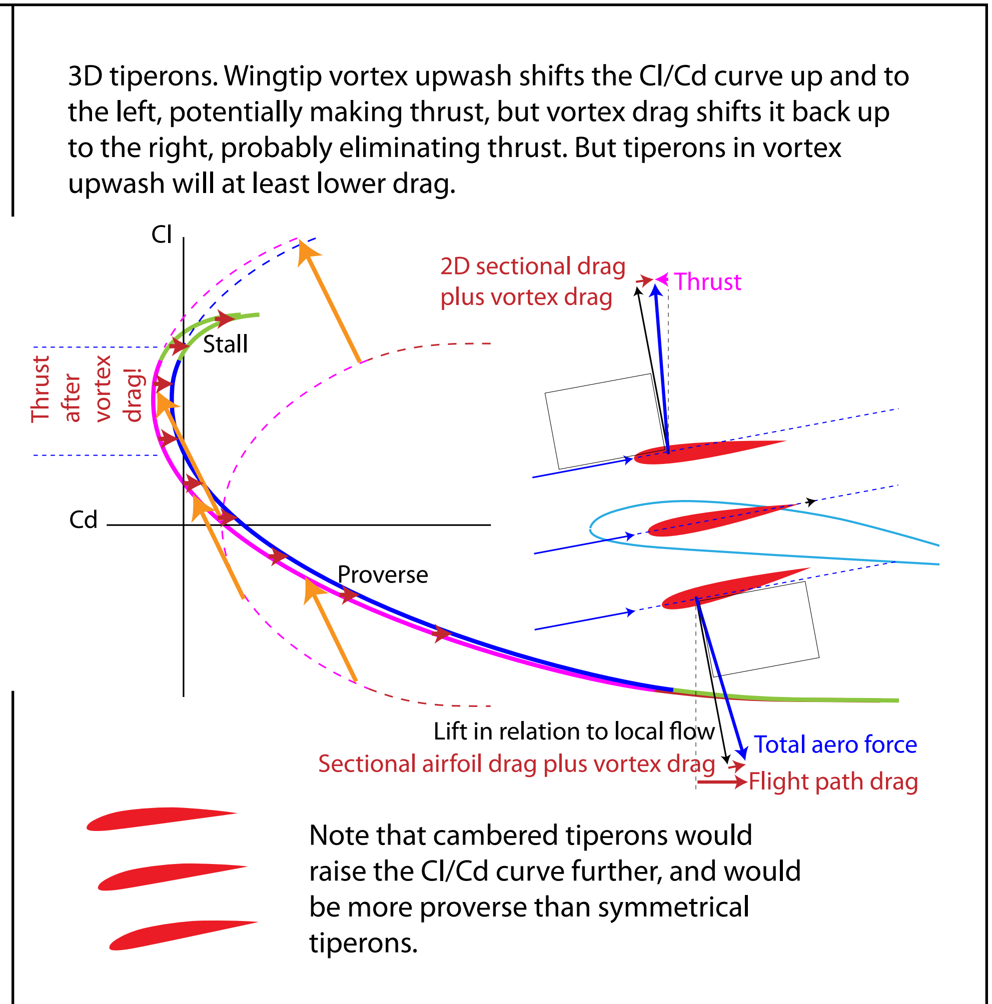


Figure 23: Upflow shifts with trailing vortex pressure drag. Even where drag is lowered, shifting the Cl/Cd curve to the left, there is also trailing vortex pressure drag, which shifts the curve back to the right. Whether thrust is achieved or not, tiperons in vortex upwash can usually lower drag.

Figure 22: Upflows shift tiperon Cl/Cd curves up and to the left, for higher lift and less drag. Locating a winglet within vortex upwash raises its lift coefficient in terms of flight path. That is, it gains lift from upwash. And its lift vector may angle ahead, attempting thrust, or at least fighting trailing vortex pressure drag, moving the Cl/Cd curve to the left.

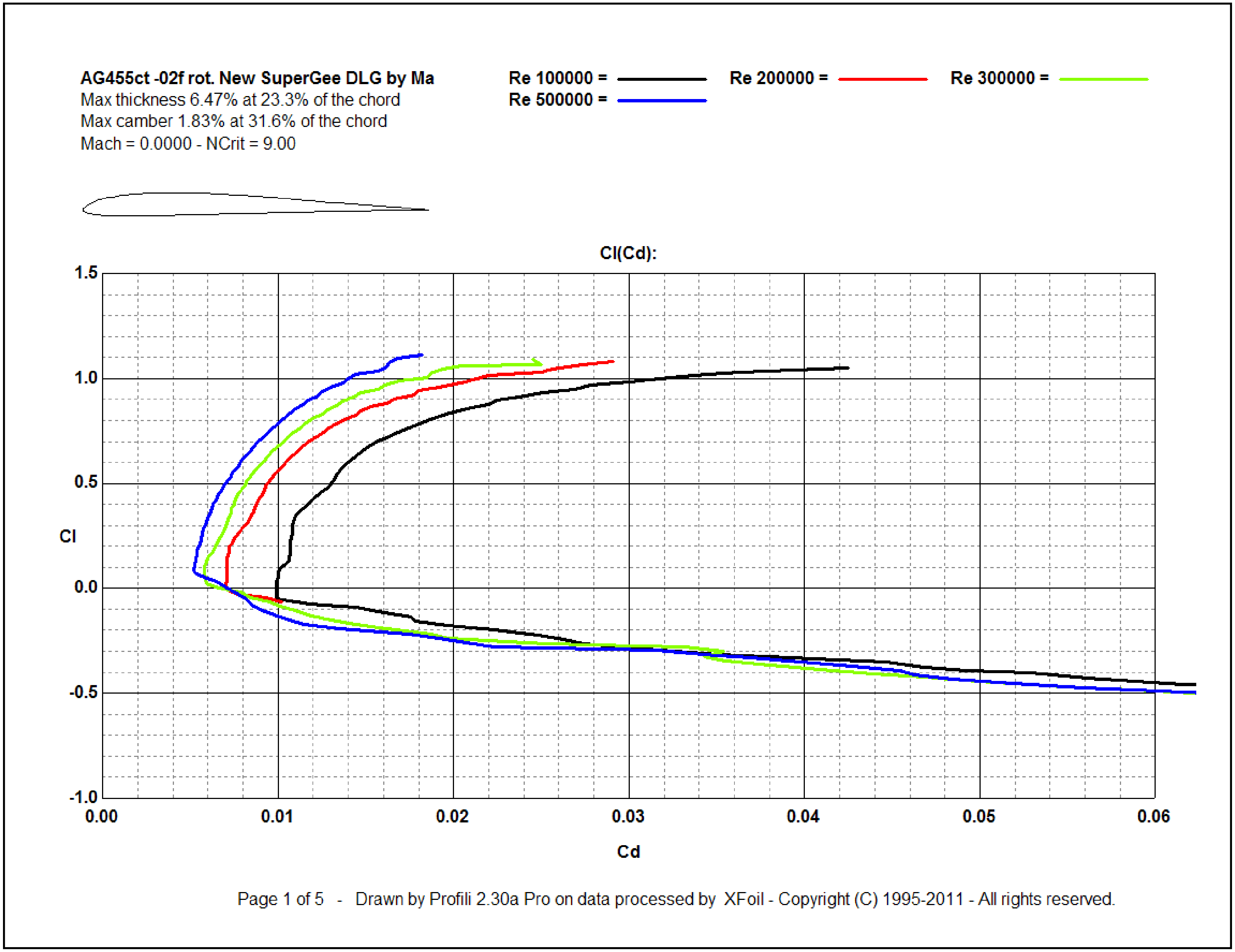


Figure 24: The AG455ct is fine for discus-launch gliders, but has a narrow range of negatively sloped Cl/Cd curve. Profili plot by Adam Weston.

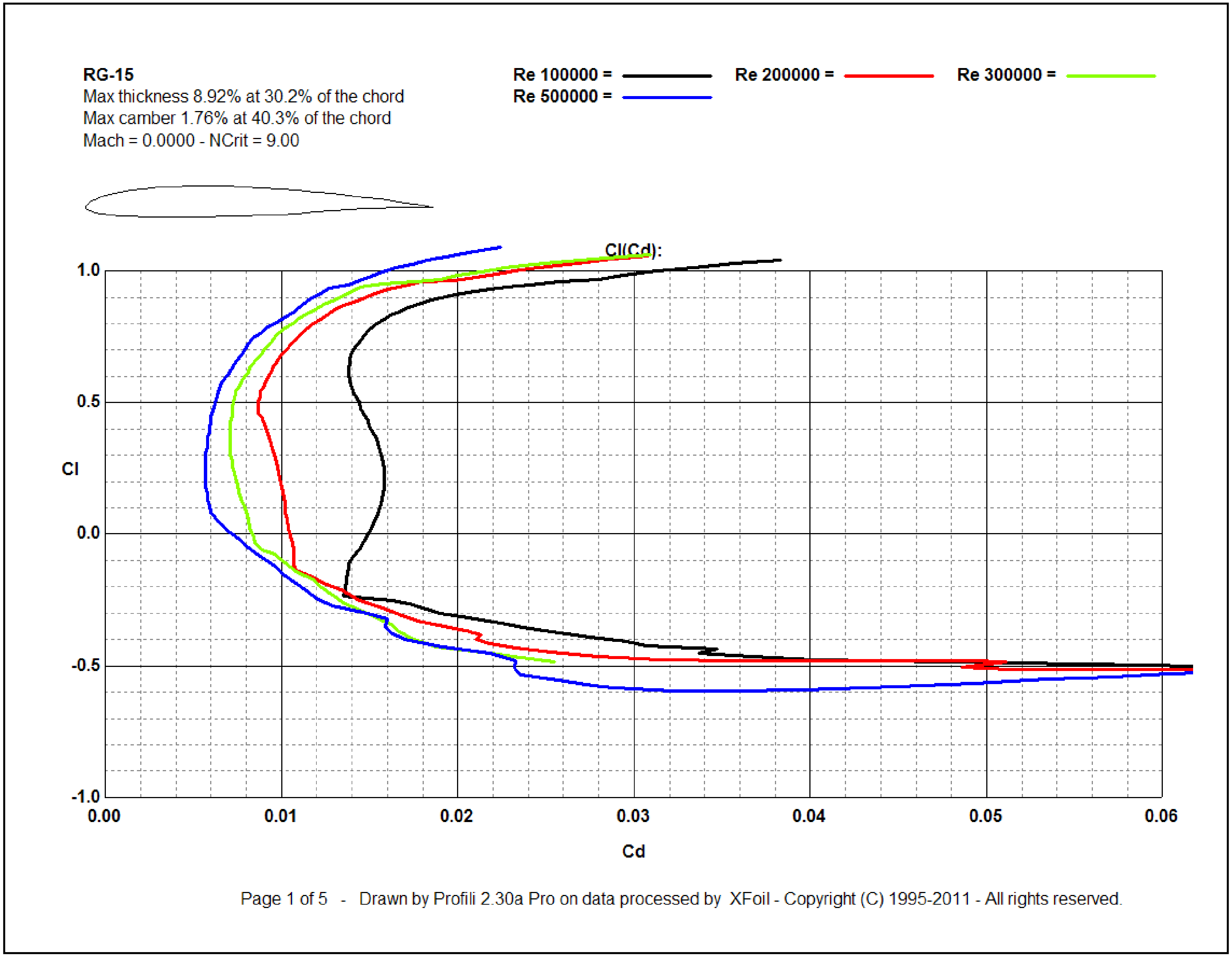


Figure 25: The RG15 is a great airfoil with a broad drag bucket, but flying its negatively sloped lift/drag curves for proverse roll/yaw could be tough, and might result in sudden oversteer if wingtips were in negative lift. Profili plot by Adam Weston.

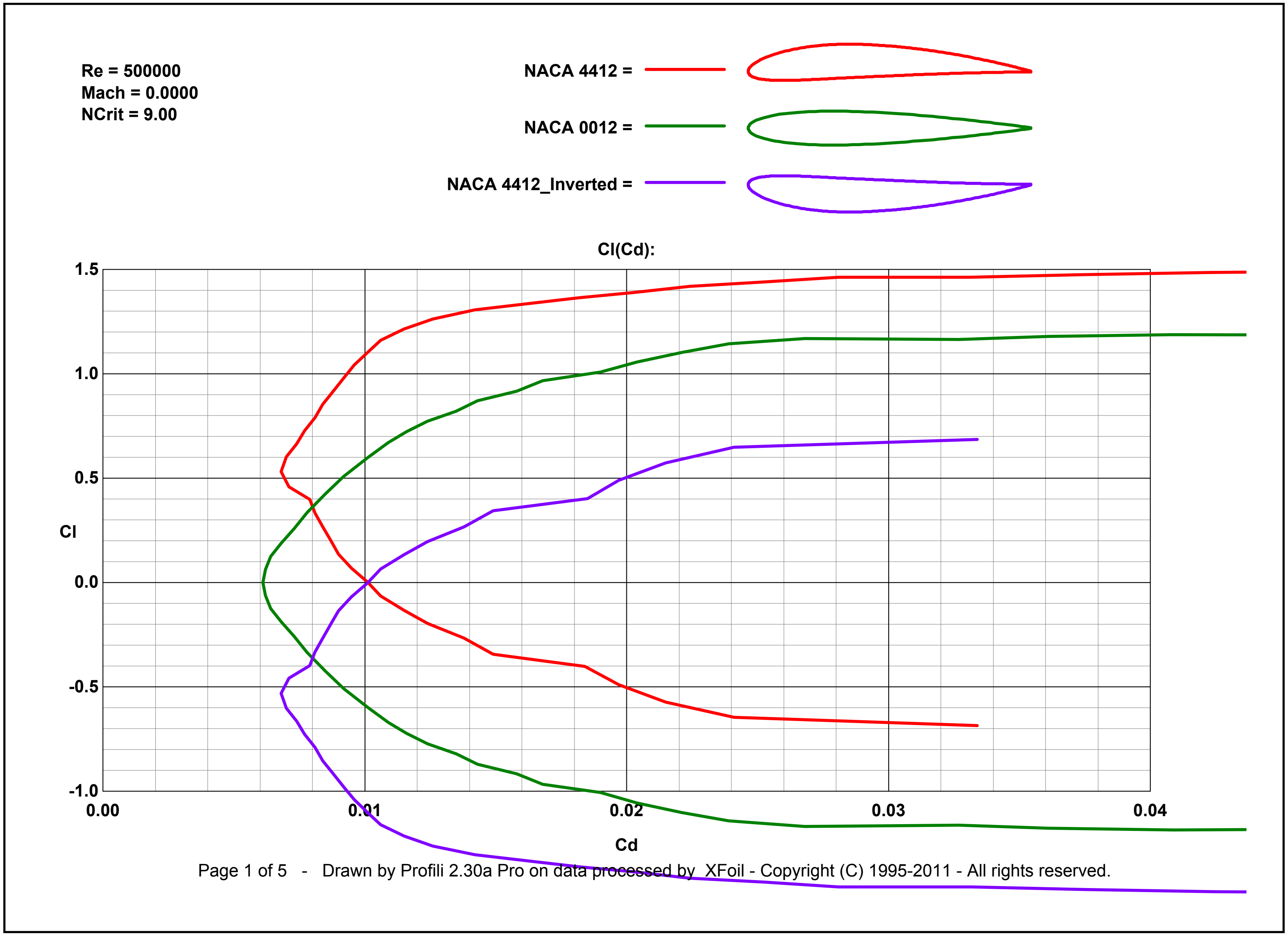


Figure 26: The NACA 4412 has predictable, negatively sloped Cl/Cd curves at low but positive lift, and thus would be fairly good for proverse roll-yaw tiperons. Contrast the NACA 0012 symmetrical foil and NACA 4412_ Inverted foils. The latter probably could only make proverse roll-yaw coupling as a tip stuck into the strongest of vortex upwash. Profili plot by Adam Weston.

Aileron differential

Aileron differential exists when with given input, from yoke or transmitter stick, one aileron deflects up more than its opposite deflects down. On some airplanes and models it's mechanically built in. RC flyers usually set up differential from programmable transmitters. Model airplane manufacturers typically suggest the amount of up and down throw for ailerons. RC flyers also can easily try what works.

See Figure 27

For most wings downward deflection of an aileron increases both lift and drag, making an adverse roll-yaw force. Downward deflection of an aileron generally moves lift up into the strongly adverse part of the lift/drag curve. Aileron differential minimizes this force by lessening downward aileron deflection.

The upward deflection of an aileron may slide its lift down into the area of the lift/drag curve where lift decreases as drag increases, for a proverse yaw force.

And how well does this work? It depends on the lift-drag curves of the portions of the wings with ailerons.

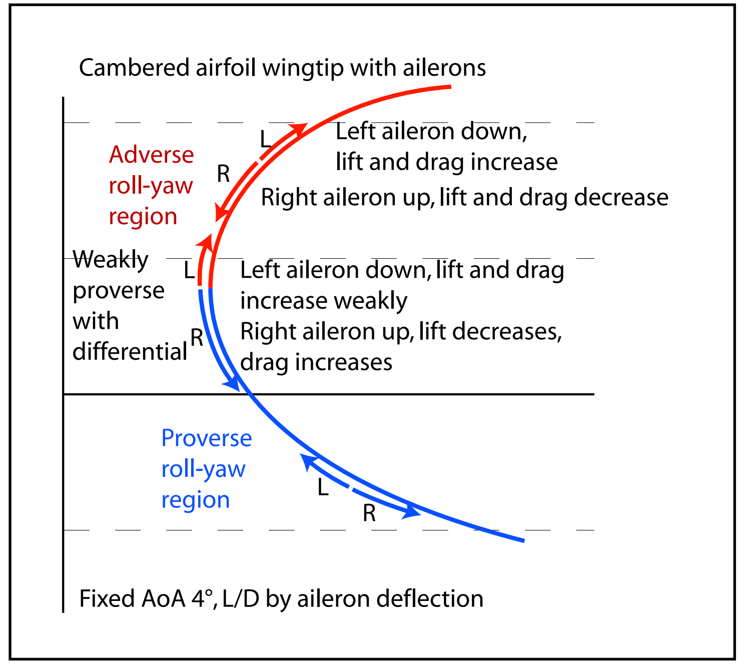


Figure 27: Aileron, tiperon, or wingeron differential.

Proversely stable thermal turns and spins, even with no aileron deflection

Sometimes after initiating a turn a model glider will tend to stay in the turn, even when the ailerons are allowed to return to neutral positions.

In a tight turn in still air, left and right wings sink at the same rate. The inside wing has lower forward velocity and thus a higher angle of attack. The result is indeterminate – the lower velocity makes lower lift and probably lower drag, but the higher angle of attack makes a higher coefficient of lift and probably higher drag, at least till it stalls. It's more pronounced in a glider in a tight spiral. When its inner wing's higher angle of attack moves the lift/drag up into an area of the curve where lift flattens and drag increases, then there may be a combination of low lift (from the low speed) and high drag. Proverse roll-yaw coupling now requires minimal aileron deflection.

In a spin the outside wing is flying but the inside wing is shedding vortices, for low (stuttering) lift and very high drag. Spins are a generally undesirably stable excess of proverse yaw forces. Even with no aileron input, spins are proversely stable turns.

Closely related: ubiquitous examples of small fins stuck into wingtip vortices to reduce drag

The winglets on most commercial jets stick up. And they're fixed. They don't swivel or have control surfaces. But they are the ubiquitous example of small fins stuck into the wingtip vortices to reduce drag. They are designed to improve efficiency at cruise speeds and altitudes, where most of the fuel is spent. Any savings at other speeds is fortuitous. Since they are generally vertical they don't directly add lift. They do angle into the inwash above the wingtip to gain a bit of thrust. It is your author's conjecture that a major part of what they do is move the center of the wingtip vortex up and slightly in, for two additional effects: It gets the lowest-pressure center of each wingtip vortex above the wing where it (1) doesn't 'pull' back directly on the wing and thus reduces drag, and (2) speeds airflow across the top of the wing for increased centrifuging and increased lift. They also lengthen the pressure gradient around wingtips for a broader, softer, lower velocity wingtip vortex center and lower pressures atop the wing.

Now, especially at lower speeds, if winglets swiveled and were horizontal, they'd be proverse roll-yaw coupling control surfaces -- tiperons.

Optimal tiperons, morpherons

Birds have the ultimate morphing wings, plus the millions of years of bio-flight-computer evolution to do the right thing at the right time. Birds don't require rudders, though they can twist their tails to achieve rudder-like control when they choose.

Some compromise of ELD and BSLD wings, perhaps with tiperons, may make flight easier on a pilot and even improve structural, weight, and lift/drag efficiencies. And it is always possible to sacrifice performance for stability. But chances are no pilot-controlled rudderless solution will avoid oversteers, understeers, or adverse roll-yaw coupling perfectly. Hence in full-scale airplanes without fly-by-wire controls rudders are here to stay. Mostly. Zagis and many hang gliders get by just fine with fins, partly due to the dihedral effect of swept wings.

Commercial aircraft winglet designs are optimized for one speed, cruise. For that speed winglet height, and each local chord, airfoil, and angle of attack can be optimized. A tiperon or a BSLD wingtip with ailerons is harder to optimize. But for each part of the vortex upwash at each speed there will be an ideal combination of left and right airfoil shapes and angles of attack that will optimize proverse roll-yaw coupling without creating so much lift that the vortex is chased outwards. Only a morphing wingtip could achieve perfection. Worse, the more flexibility in a wingtip the more chance of destructive flutter. The ideal provides a target. Reality requires compromise, simplification, and most often, rudders.

See Figures 28 and 29

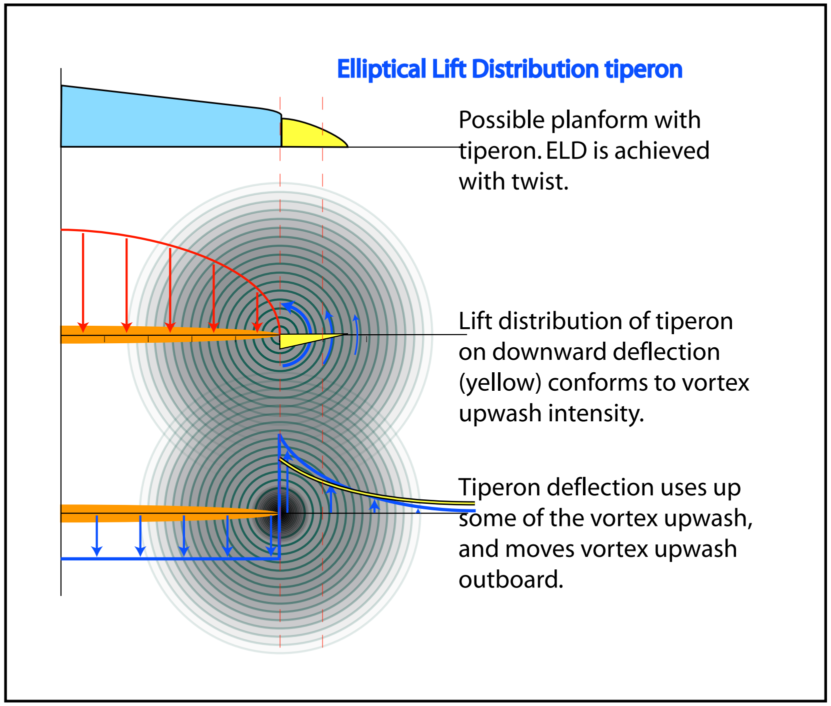


Figure 28: On deflection, tiperon lift distribution should conform to the pattern of wingtip vortex upwash angles. Where vortex upwash is weak local tiperon sectional lift should be weaker.

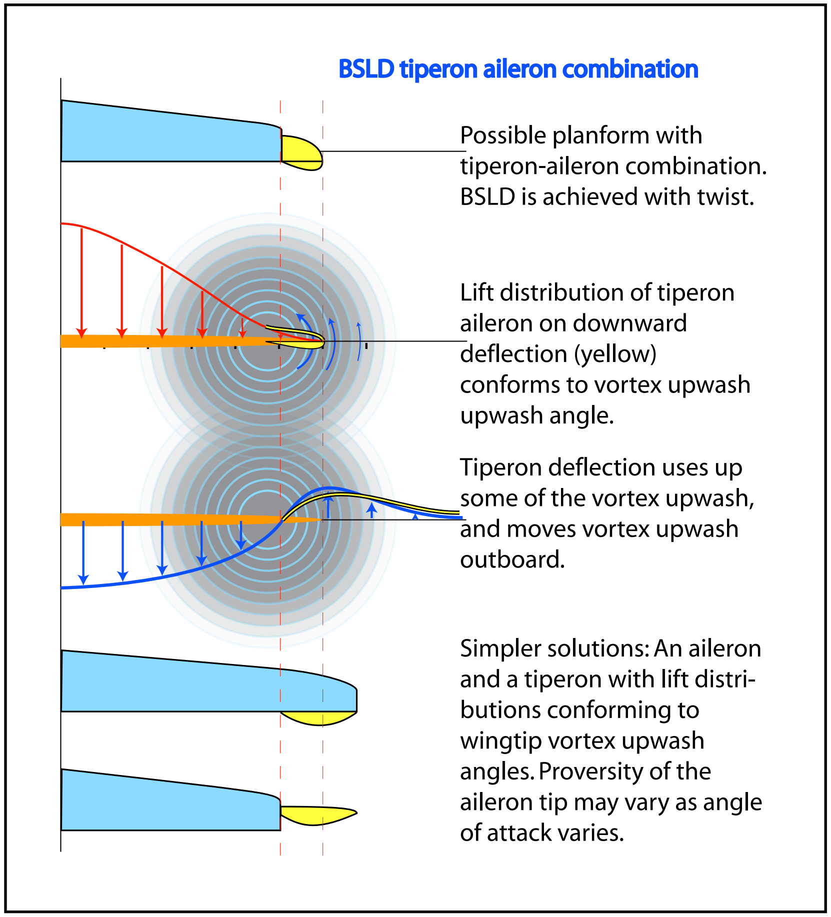


Figure 29: To make BSLD wing's tiperon's lift distribution conform to the pattern of wingtip vortex upwash is more complex. Ideally the tiperon/aileron shouldn't make sharp transitions in lift that form local vortices and drag. To operate the wingtip at low angles of attack while the main wing operates at varying angles of attack, the wingtip may need to be a tiperon. To get its lift to conform to varying angles of wingtip vortex upwash an arc-shaped aileron may be required, or even one which warps to provide arc-shaped lift. A simpler compromise is to just use a wingtip aileron or a twisteron.

(Endnotes)

i Philip Randolph, "The Nurflugel Mailing List, a Discussion of Historic and Modern Flying Wings. - Yahoo Groups," accessed March 31, 2014, https://groups.yahoo.com/neo/groups/nurflugel/conversations/messages/13938.

ii Bill Kuhlman, "Twist Distributions for Swept Wings, Part 4," *Radio Controlled Soaring Digest*, June 2003, 3, http://www.rcsoaringdigest.com/OTW/on-the-wing4/164-HCP4.pdf.

iii Mark Drela, "Mark Drela Quoted on RC Groups," accessed March 31, 2014, http://www.rcgroups.com/forums/showthread.php?t=1748293&page=2.

iv Bill Crawford, "Flightlab Ground School, 3. Three-Dimensional Aerodynamics," www.Flightlab.net, 2009, 3–4, http://www.flightlab.net/Flightlab.net/Download_Course_Notes_files/3_Three-DimensionalA%232BA154.pdf.

v CW Fan, "Incompressible Flow over Finite Wings, Chap. 5," December 2003, 10, http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCkQFjAA&url=http%3A%2F%2Fwww1.ytit.edu.tw%2Fedu%2Fme%2F145%2FA05.ppt&ei=SnBRU7n4CMyVyASnpIHwAQ&usg=AFQjCNGJxMm2ES9WGgDho25pdUiGoL0Bdw&sig2=a7Wx_Fyf5nJ1lJvaBNkArA.

vi Kuhlman, "Twist Distributions for Swept Wings, Part 4," 16.

vii Robert T. Jones, Wing Theory (Princeton University Press, 1990), 113.

viii Robert T. Jones, "Minimizing Induced Drag," *Soaring*, October 1979, 26–29.

ix Drew Landman et al., "Wind Tunnel Testing of the Wright Brothers Model B Airfoil," AIAA 2001, no. 0310 (n.d.): 5, http://www.wrightexperience.com/pdfs/airfoil.pdf.

Sixteen Foot Flying Wing for Slope and Aerotow

It seemed like a good idea at the time

Steve Pasierb, spasierb@optonline.net, John Appling and Erich Schlitzkus

A 48 inch span flying wing can be good fun. An 8 foot span flying wing is better. A 16 foot span monstrosity of a wing is just plain stupid!

Born out of mortal combat at the spring 2013 Cumberland Maryland Soar For Fun and blended with both a dash of capability a dose of culpability results in a bad idea realized. Sure, we could double the span of the classic Bash Enterprises Mongo, an 8-foot flying wing. But instead of smartly making it 16 feet by adding long tips -- as the few Super Mongos produced once did -- let's make the whole thing 200 percent of the original?! And, change the airfoil. And, well, change everything else.

While Steve Pasierb is the instigator of this project, the majority of the thinking, design effort and plain old hard work cutting foam cores for four wings, was

that of John Appling. He'll be picking white foam beads out of his house and Jeep for the next 10 years!! A third wing was constructed by Erich Schlitzkus.

What goes into one of these wings? A whole bunch of four-foot EPP and expanded bead foam sheets, a pile of pultruded fiberglass tubes and rods, The better part of a quart of polyurethane Gorilla Glue, rolls and rolls of two-inch fiberglass strapping tape, many square feet of Oracal self-adhesive sign vinyl, a roll of servo wire, add eight 235-ounce torque metal gear servos plus a tow release set-up, throw in a receiver (or two) and provide some electrons. Easy peasy!

Our spokesmodel poses with raw cores in the summer of 2013. Main body of the wing is white expanded bead foam while the leading edges are expanded polypropylene foam.

Spar and joiner stock. Spars are 1 inch OD and ¾ inch OD pultruded fiberglass tubes to add span width rigidity to the panels. Joiner tubes between panels are a mix of 1 inch and ¾ inch with ¾ inch and ½ inch fiberglass in both tube and solid rod formats. This first picture, #4, is all the four foot spars/joiner segments sufficient for two completed wings.

Construction of the control surfaces was left to the preferences of each builder. Shown here in #5 is Steve's balsa elevon stock for the tips of the yellow wing. The other two wings used the foam core sections sheeted with carbon and fiberglass in a traditional vacuum-bag.

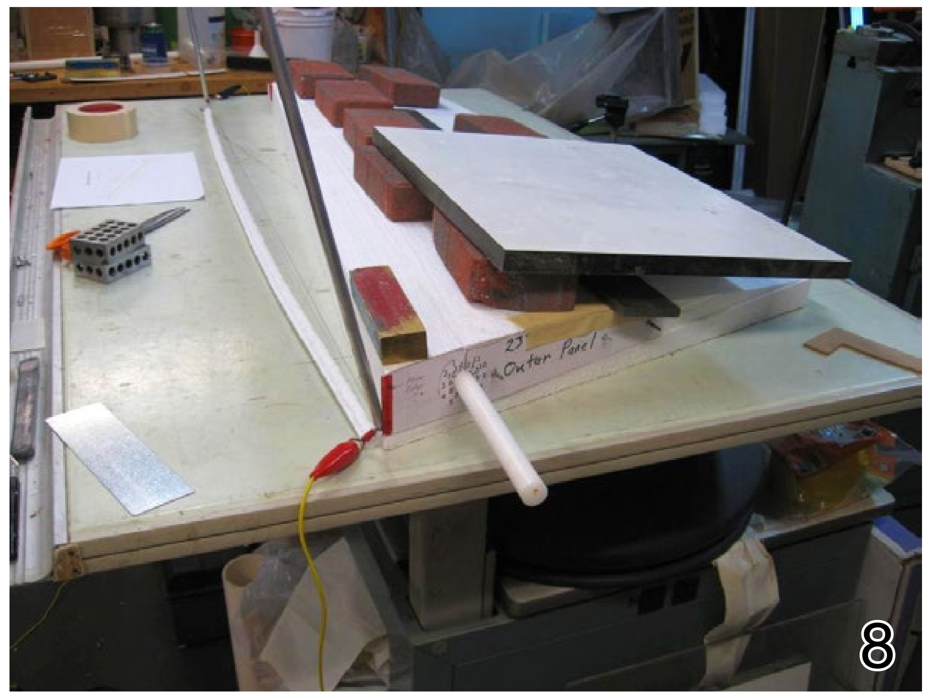
Panel cutting was completed in Maryland. Shown in #6 is John's set-up to hot wire the lower surface of a starboard inner panel. The foam blank is positioned on a 40" X 60" drafting table. The hot wire bow handle that is resting on a brick will be hung from a traveler suspended by winch line attached to the ceiling joists.

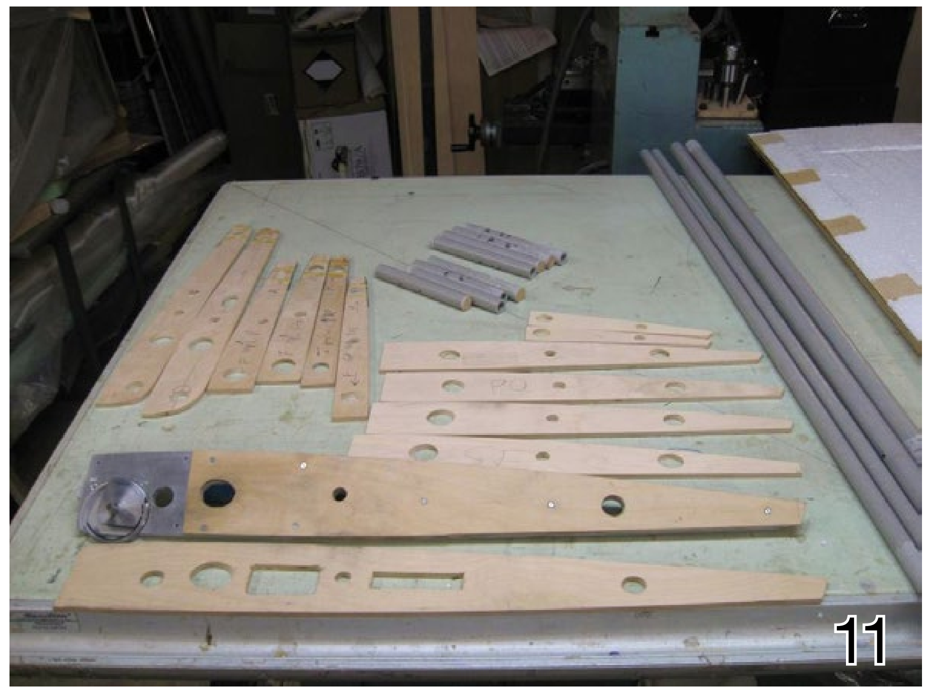
Before committing to cutting the spar holes in the foam, a confirmation of the spar's strength for the inner panels was in order. Photo #7 shows the 48" long 1" OD glass tube holding 20 pounds in front of a second tube. Deflection appears to be about ¾". 3" pieces will be added to each spar to achieve the required length.

The spar holes were cut with a hot wire simply following a circle template.

Confirming the ¾" hole in the outer panel is to size. The foam "rod" removed from the hole is shown in front of the core in #8.

To get to the proper CG (15% - 20% of MAC) we decided to do some calculations to determine the moment about the CG. Good thing we double checked because the amount of ballast planned was close but the location needed to be moved WAAAAY forward of what was anticipated.

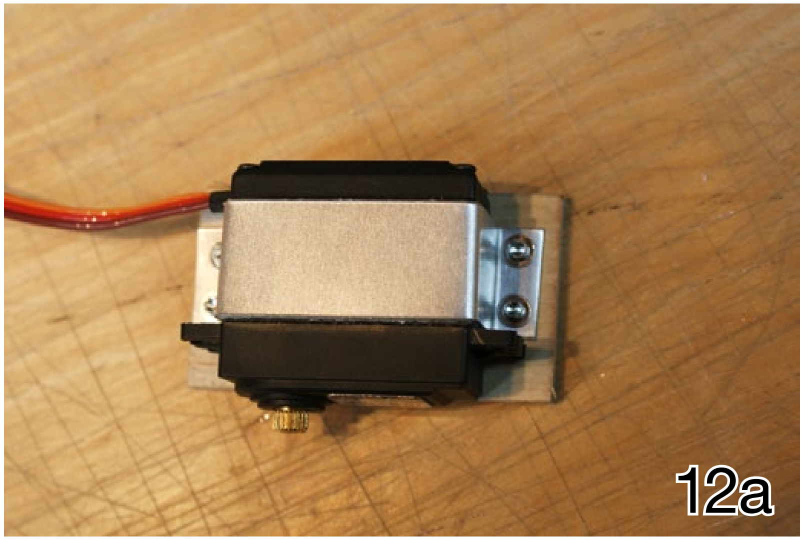




So no expense was spared to create a gas-fired foundry and custom mold to produce two lead ingots. See Photo 9. What the wife doesn't know won't hurt.

Photo 10. This should get us within a workable range to fine tune the CG using slugs of lead in the 1 inch OD X ¾ inch ID main spar tube. Using 2 inch lengths of EMT, John cast slugs that were oversize in diameter and turned them down on a lathe to fit neatly inside the main spar tubes.

Photo 11 is an image showing the pieces that went into the four panels of John's wing. Ribs (two on each panel), sub ribs (to anchor joiner tubes), joiner tubes and spar tubes. If you look at the rib second from the bottom you will notice John went with the more complex, heavier and labor intensive releasable tow mechanism. It just "seemed like a good idea at the time."



12a

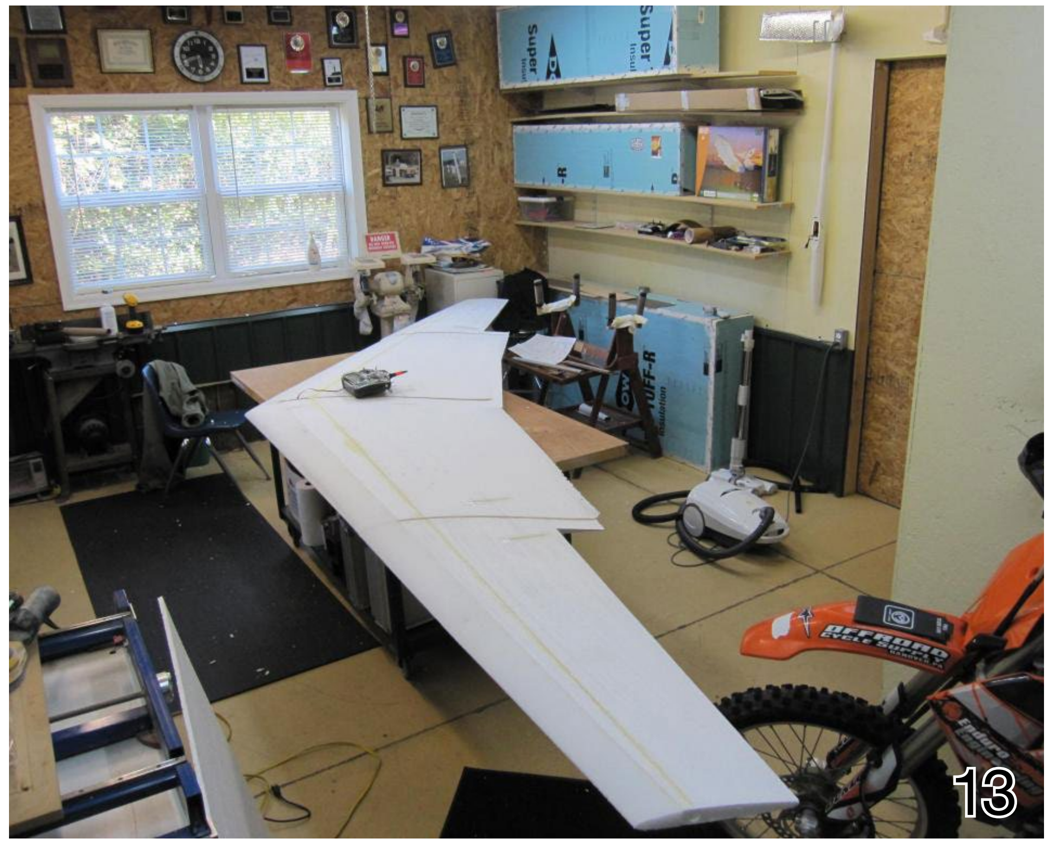
12b

Servos were installed in the wings built by Steve and Erich using a "top-hat" approach of a plywood plate base and traps of bent aluminum sheet screwed to the plate. Details of this installation can be seen in Photos 12a and 12b.

Wing #3 while under construction in Pennsylvania can be seen in Photo 13. It quickly fills Erich's workshop!

The plan on this one is to have a simple elevon, approximately two feet in length in the center of the main panels. Again, each wing build was done differently based upon the personal preferences and dementia of each builder.

OK, this is when things starting getting a little crazy for Erich. After putting the wing together and trying to pick it up, it was easy to see that we would need more carbon to stiffen the main panels. It was like a darn seagull flapping in the wind.



13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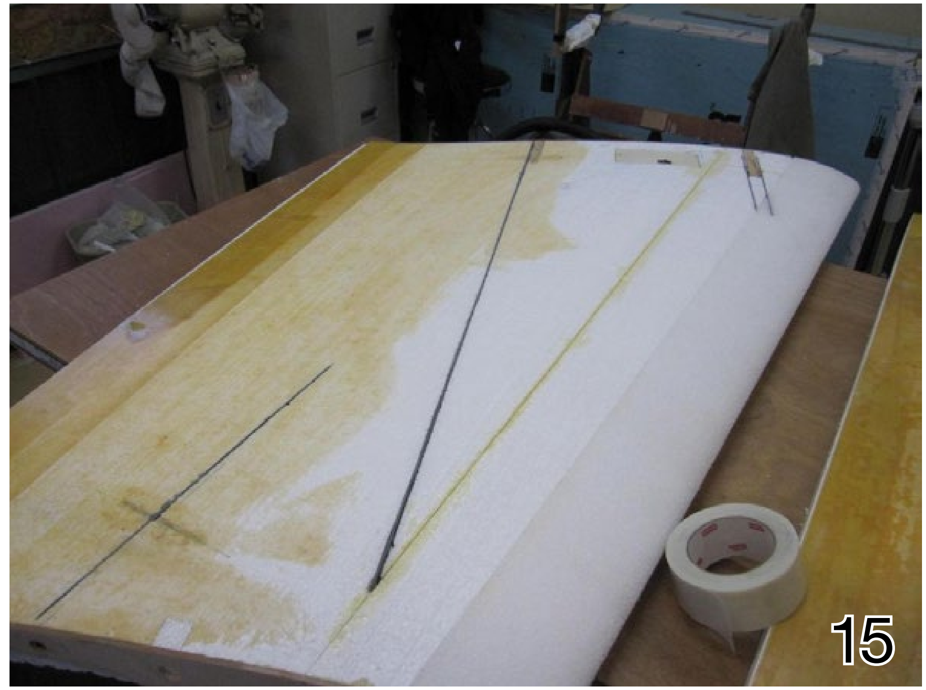

15

As shown in Photos 14 and 15, on the inner panels, a router with a 0.125" bit was used to make slots for 1.0 inch tall carbon which was then put in place with epoxy.

This addition made a significant difference.

The wing was now ready for several rolls of packing tape.

Meanwhile, up north in Connecticut, wing #2 was at a similar stage.

Right wing is shown here in Photo 16 all prepped with trailing edge carbon sheet cut to size. The carbon was installed with 3" fiberglass tape and epoxy overlapping the surfaces.

Balsa elevons for the tip and main panels were vacuum bagged with 3 ounce fiberglass and carbon mat on the bottom for stiffness. See Photo 17.

In early January, Steve finally got to unwrap his Christmas present from Erich! Combination tow hook and tow release mount. On steroids. Shown in Photo 18.

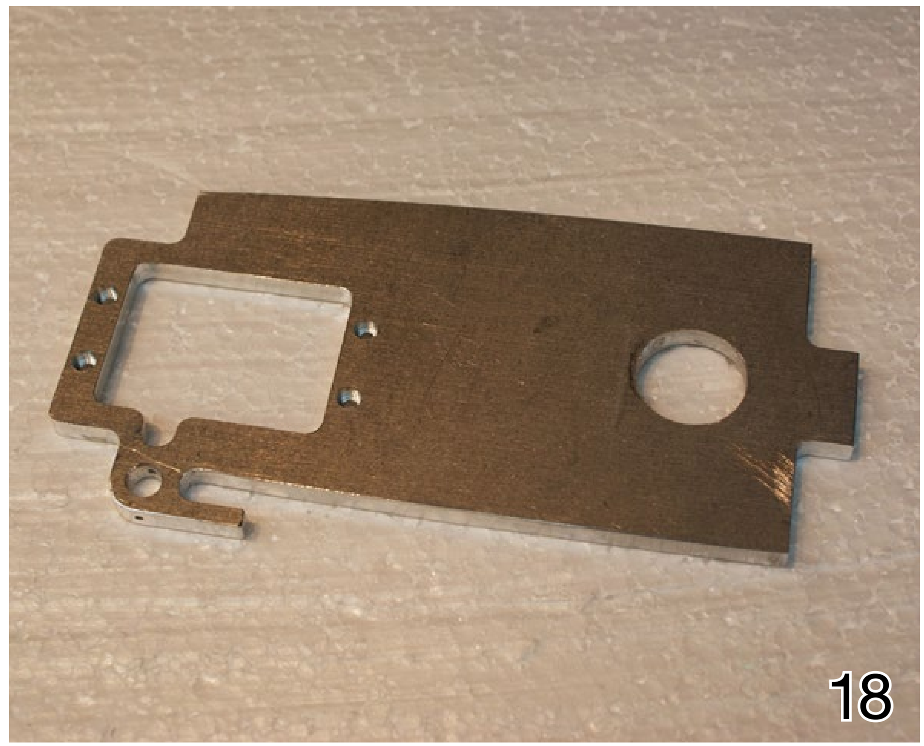
Main joiners are shown Photo 19 on Steve's wing. Each is a solid fiberglass rod. Each rod tube is captured at the root and also at a sub root 9 inches into the panel.

Gorilla Glue makes everything inside the core as strong as possible. The glue is the yellow you see on the foam. The small hole in the middle of each section is a fill spot Steve used to add extra glue once the tubes were in place.

Yeah, as can be seen in Photo 20, this baby is not designed for transportation in a compact car.


16


17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The lead ingots to achieve CG balance are shown in Photo 21 all tucked in place on the top side of the main panels of Steve's wing. The cut-outs were then capped with pink extruded foam.

When it all cured, Steve restored the airfoil shape with a sanding bar, easily sculpting the foam.

Photos 23 and 24 show the top and bottom tip strapping tape scheme employed by Steve. The main panels have much more aggressive use of strapping tape.

Photos 24 and 25 show covering the tip panel bottoms with orange Oracal vinyl.

Covering tip panel tops in yellow for a bit of contrast in flight is shown in Photos 26 and 27.

We used 3M 77 under all the wide strapping tape (dust it on as the new propellant can eat foam) and then a full dusting of 77 under the vinyl even though the vinyl is a self-adhesive product. The finished panels appeared to be incredibly stout.


WE NEED TO START
BUILDING
AGAIN.

24


BUILDING
AGAIN.

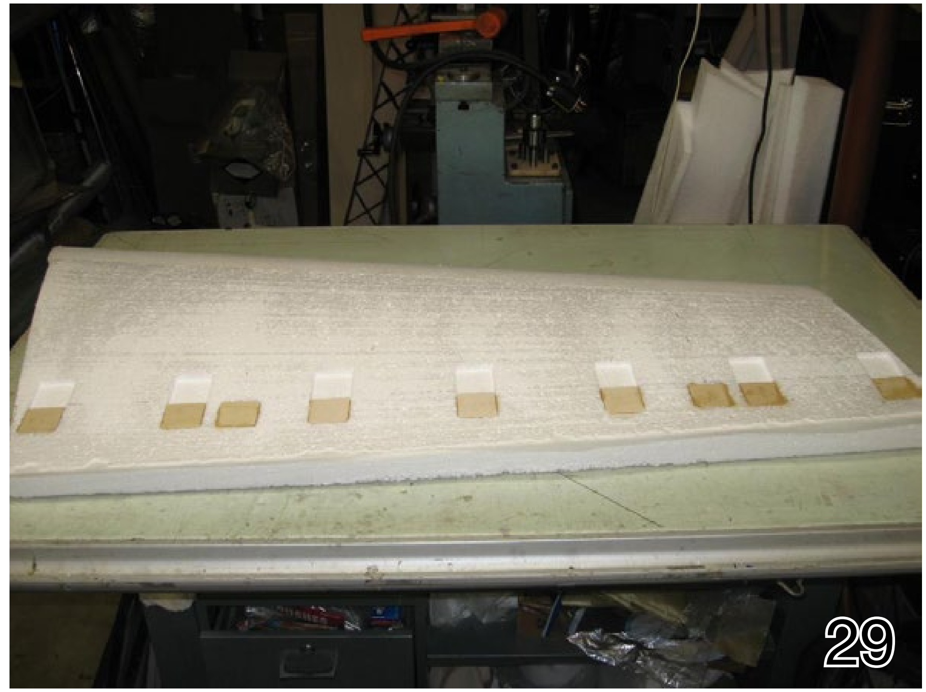
25


ORACAL
ORACAL
WE NEED TO START
BUILDING
AGAIN.

26

27

28

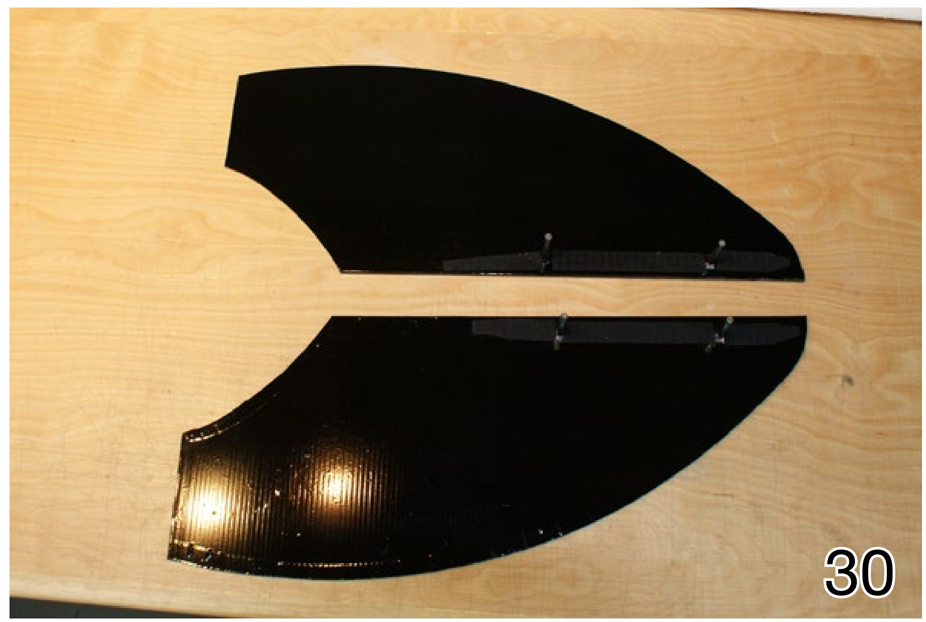


29

Photo 28 shows servos in place, wiring completed and control horns installed. Just waiting for the elevons. Steve installed his elevons with sections of 2" strapping tape perpendicular to the hinge line, the hinge lines were then fully sealed with vinyl hop and bottom. This is the final stretch of construction!

Contrasting to Steve's approach, John used aluminum piano hinge cut into short lengths. Show here in Photo 29 is a core section with hard points installed to accept the hinges.

Each tip on the yellow wing is made of Coroplast material covered in black vinyl, shown in Photo 30. They attach with two fiberglass pegs that insert into the tip root, and are held in place with sections of Velcro. The yellow wing used two large tip sheets. The other two wings used slightly smaller vertical surfaces between each panel. Both approaches appeared to work equally well. The vertical sections between the wing sections look much cooler!



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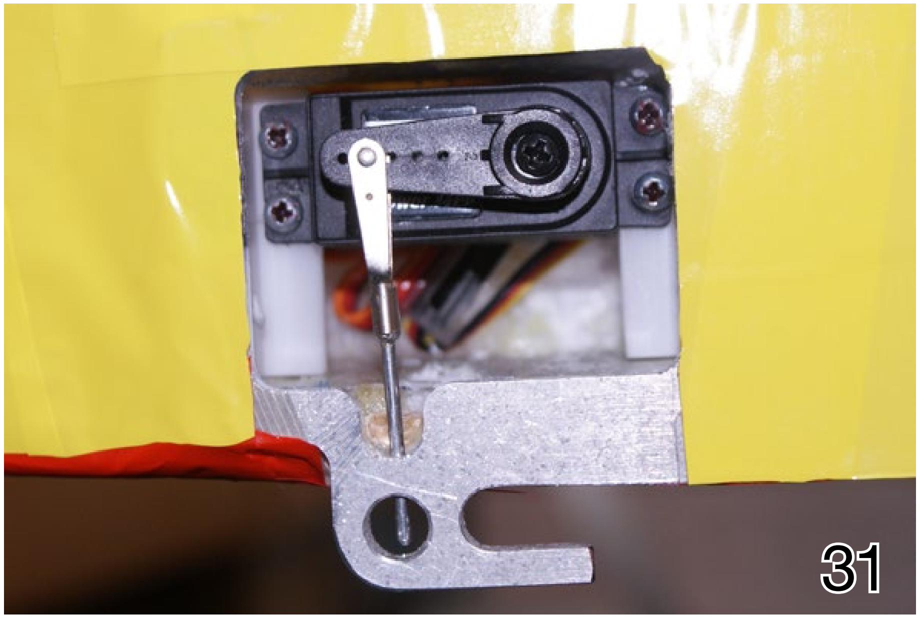

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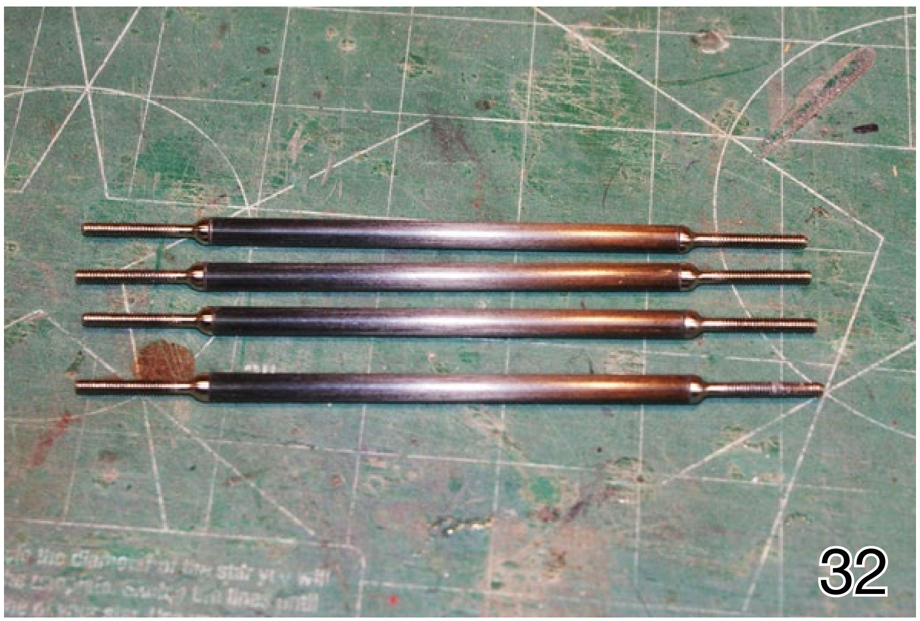

32

33

Photo 31 shows the tow release installed and working perfectly. Another 235 ounce torque metal geared servo.

Making up carbon + tungsten pushrods, Photo 32.

This sucker is massive in its final state ready to fly. Steve's large center island workbench is dwarfed! Wing sections are just slid together for Photo 33, not securely taped.

For ease of assembly, each wing half of Steve's model has its own switch, 2.4G receiver and battery. The receivers are simply both bound to the same program in the transmitter. The switches are recessed. You can see the receivers to the side of each switch in Photo 34.

Oh, and as you can see in Photo 35, it does have a "bottom."

Test flights. Technically, wing #1 built by John flew twice in the November of 2013, just slightly exceeding the Wright Brothers' distance record, but with lesser results. It became quickly obvious that this beast needs to be aero towed. Forget the bungee. Remember, this is NOT a copy of a Super Mongo (standard Mongo with skinny tips added) this is a 200% Mongo. As they say in Brooklyn, it's freakin' euge!

Bungee technique is a four to five person ballet operation as evidenced in Photos 36 and 37. Towing it ROG will be a much better solution.


34


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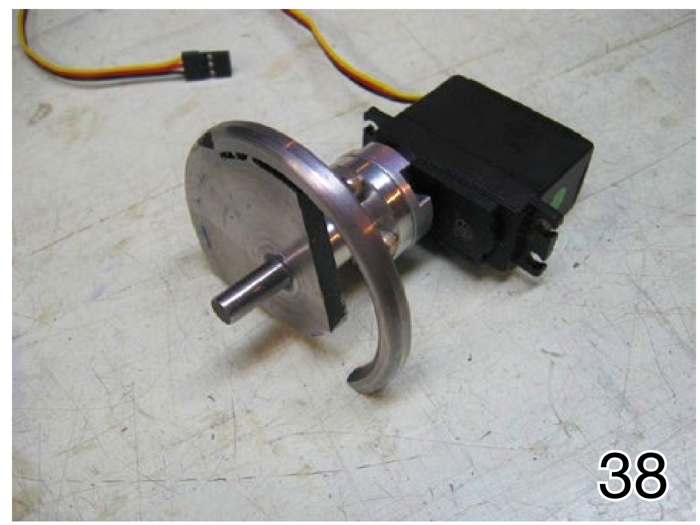
36

37

On flight #1, the bulky tow release stripped the servo when released under pressure -- or non-release as the case may be. The resulting impact rendered the gears of the center panel servos toothless. Metal gear servos with high torque are essential on a project like this. Wings #2 and #3 received 235 ounce torque metal gear servos.

Sortie number two was done with a new tow release servo and the center panels locked in place. The good news is the metal gear tow servo worked fine. Bad news is that the center panel control surfaces are vital. And, they were likely locked too cambered instead of reflexed. The tip sections alone were not sufficient to effectively change pitch -- up elevator flexed the tips while the main body panels kept moving forward in a straight line.

While an engineering masterpiece, shown in Photo 38 is the original tow



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40a

release that caused issues on the test flight. It has since been replaced with the simpler version.

Wing #1 came away from all this excitement essentially undamaged other than needing all the servos replaced with more substantial offerings. Key to all of this foolishness and experimentation was to learn that the wing does indeed fly and it travels perfectly flat just as a lifting body should -- no tendency to be bowed in the middle. See Photos 39, 40a and 40b. At approximately 35 pounds of all-up weight, this was a bit of a concern.

It does fly! If the tow release on flight #1 had worked, it had sufficient altitude to clear the tree line and head out into the valley.

40b

Fast forward a few months. Two of the three wings then flew in March at the 2014 Cumberland Maryland Spring Soar For Fun. Pictured in Photo 41 are the creations of John Appling (The previous white test bed now done in red-white-blue), Steve Pasierb's yellow monster, and Erich Schlitzkus' gray overcast. Each is a bit different in their construction methods, but each is certainly a beast. John's wing had wiring and radio issues that kept it grounded for the day.

Towing was done by Len Buffinton flying an Aero Works Carbon Cub powered by a DA-150 motor. There was no question this mighty tug could pull against any issues that might have occurred. Without yaw control, we were concerned that the wings might slide awkwardly on the ground. These concerns were completely unwarranted.

First off, these wings aero tow fantastically. See Photos 42, 43, 44 and 45. ROG occurs in about a dozen feet and both wings that flew this day tracked perfectly behind and just above the tow plane. Towing speed needs to be kept moderate or some oscillation begins across the entire wing. More to be said on that subject later.

What they are is floaters. Majestic at that. The wing tracks well, carves nice turns and is actually a joy to fly. Steve Pasierb did the first flight of the day and everything went smoothly until he dropped the nose to gain speed to


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attempt a loop. The entire wing began to oscillate. Not an unknown quality in flying wings. The left outer elevon fluttered and he quickly returned to normal, level flight. The rest of the time in the air was a long majestic glide.

Landing was a non event as Steve turned the big wing in off the slope, made a short base leg (See Photo 46) and rolled onto final. The wing got into a bit of ground effect flying low and refusing to go lower than a foot off the turf. A shot of down control resulted ground contact and an amazingly uneventful landing.

Erich was up next with the big silver and gray wing. He also had a great flight. He had not programmed enough reflex into the control surfaces, so it had to fly while holding the right stick back a bit throughout. His wing also grooved nicely in turns and performed very well. Another long flight in the books. Another smooth landing.

Steve flew again, and it was just like gliding along with a giant woody sailplane of the 1970's. Don't push it and you'll be happy, push it too hard and too fast and odd stuff happens. A long happy flight.

Erich flew his again and that was where serious issues were uncovered. Erich and his friend Russ Bennett were trading the controls having a fun time. The wing got a bit too fast, began a shallow dive, picked up more speed, did not respond well to up elevator stick and

47

48

simply IMPLODED!! It was found near the bottom of the mountain. Half in a tree, half on the ground, as can be seen in Photo 47. Nothing salvageable. He did get the receiver back and they hauled what little litter remained back up the mountain. A giant oak tree still owns the rest.

Steve flew two more flights. On the last, the tug got too fast before turning out over the valley into the slope lift and the wing oscillation bit once again. He came off tow low, stalled and eventually flopped it onto the ground with no damage. It was time to not tempt fate anymore and put her away until next time. See Photo 48.

The verdict? More rigidity in the airframe is desperately needed! They fly great, but must be flown at slow to moderate speeds. Forget aerobatics. A structure this large and heavy is more than the typical slope wing construction of miles of strapping tape and lots of polyurethane glue can withstand. The structure needs to be much more robust and stiff. Erich's was taped, cross taped and glued at wild excess, had a carbon cross member and it still did not survive. It's just too damn big!

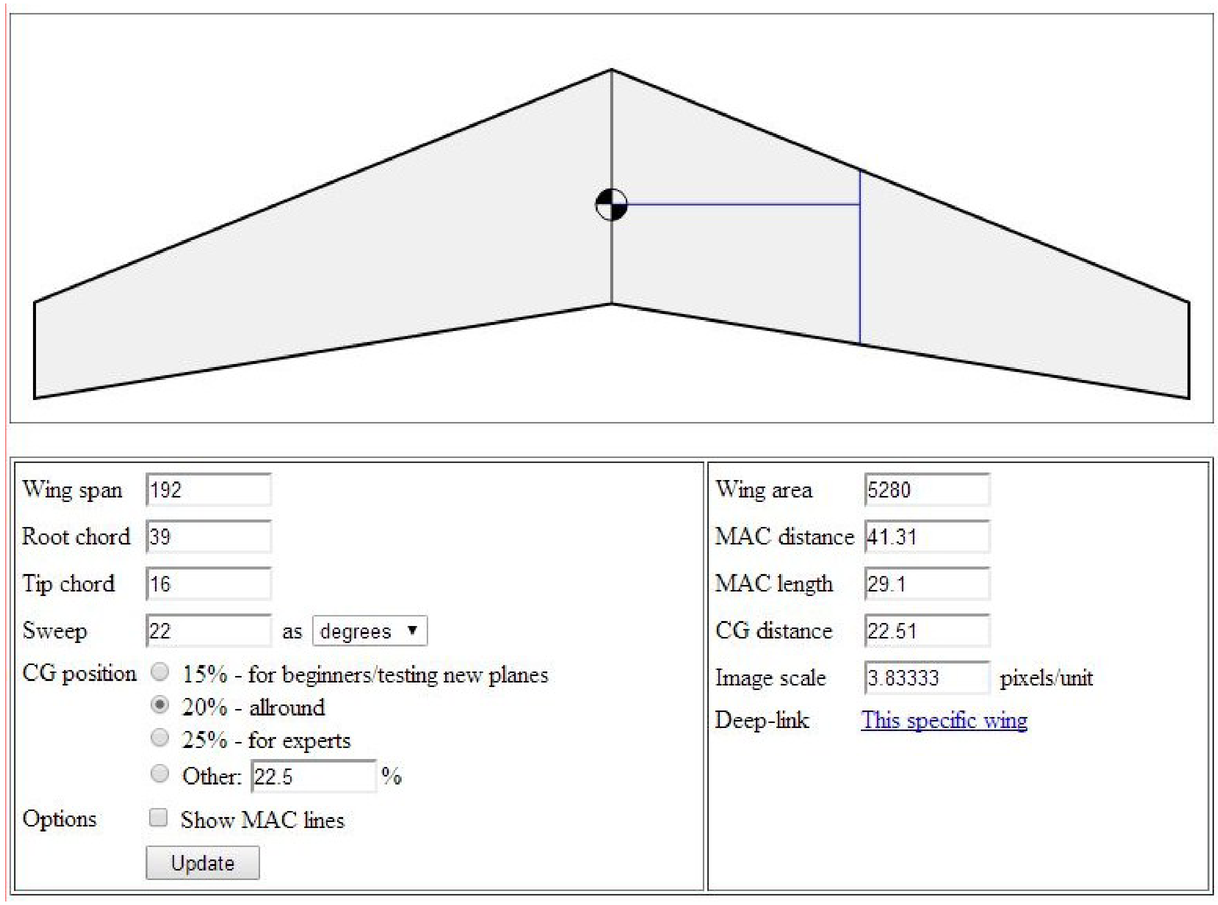
While much thought was put into the spars to provide strength across the span, as a lifting body the primary issue is panel rigidity. The wing does need to resist bending into a giant "U" shape under pitch control, but twisting forces at speed are its worst enemy. Knowing what we do now, there would still be a significant spar in the main panels, but the tip panels appear to be in less need. Reinforcement, running in a diagonal orientation (think Disser wing) to prevent twisting needs significant thought and improvement if there is ever to be a 2.0 version of these wings.

Steve's plan at the moment, although his is still in one piece, is to cut the center panels approximately in half, reducing the huge chord, total area and total weight significantly. The center will become one rigid section with a major spar. The two tips will receive more cross reinforcement and plug into that. We'll see in a couple months what a more rigid 12 or 14 footer will do?!

John's 16 foot wing will likely get a test tow at an aerotow event this summer. That should be fun, but these are flat land events, not the mountain slope conditions of Cumberland, MD.

The "Mongostrocity" as it has come to be known, is still a work in progress. Stay tuned.

As we've said all along... It seemed like a good idea at the time!



Specifications

Airfoil:	MH-64	Washout inner:	0 degrees to 0 degrees
Span:	192 inches	Washout tip:	0 degrees to - 2 degrees
Root chord:	39 inches	Elevon root:	7.8 inches max (20%)
Tip chord	16 inches	Elevon tip:	3.5 inches max (22%)
Sweep angle:	22 degrees	LE material:	1.3 lb/cu ft EPP
Area:	5280 in. sq.	Panel material:	1.3 lb/cu ft expanded bead styro

A 4.5m Discus 2 from Top Models CZ owned by Colin Taylor from Kapiti, NewZealand. Gotta love scale saiplanes with realistic pilots in place. Photo taken at the Burnham Aerotow in March of this year by Graeme Phipps. FujiFilm FinePix JX370, ISO 100, 1/180 sec., f11

(Complete coverage of the 2014 Burnham Aerotow event can be found in the May 2014 issue of RC Soaring Digest.*)*

Jerilderie Scale Aerotow 2014

Henryk Kobylanski, henryk@rctrader.com

With over 30 pilots coming from all over Australia, this year we had a special guest, Ross Biggar, coming all the way from New Zealand with his 6.6m Arcus in tow (pun intended). That's what we call dedication.

One of the immediately obvious things that have changed from the early years of Jerilderie is the number of tow planes that were available (I counted 12). The tugging "fleet" were kept well entertained all weekend but at times you would be excused thinking we were at a 3d competition rather than a Scale aerotow, given the number of IMAC/3D tow planes. As much as they are not totally a scale look, the idea of these airframes is more functional than visual. They make for one of the most stable towing platforms with very friendly landing characteristics, which is an important aspect when a pilot can tow up to 50 sailplanes per day.

From the outset, Jerilderie was always a "big sky" event allowing for the flying of large scale sailplanes. The thing that has become very obvious over the past 10 years is that the average size of the sailplanes has increased. With notable exceptions, namely Bill Bland's half scale sailplanes, in the beginning, third scale was the exception. This year, it really seemed the norm, with the majority of sailplanes being round the 1:3 scale and a few pushing the 1:2.5 barrier. With such a lot of investment in airframes, the other significant difference was the number of trailers transporting them. In Jerilderie's first year there may have been one or two, and again the 10th anniversary shows how much more the average person in investing in the sport.

Pilot briefing

Some of the tow planes

Jim navigating the pits

Morgan Hill, Rod Watkins and David Hobby ponder if the weather is quite perfect yet...

was wonderful to see that Martin, now a resident of Melbourne, had made the trip to Jerilderie and brought with him some of his wonderfully handcrafted models. Two of the outstanding vintage models were Martin's beautiful Golden Wren and Leon Carlos's meticulous Fafnir.

Unlike past years, the weather was very mild and probably the greenest we have ever seen the racecourse. This did not affect the fine flying conditions and other than the odd windy morning, flying went on right through to Tuesday afternoon.

Sunday night saw us have the communal BBQ in the Racecourse Pavilion. With meat sizzling and wine-a-flowing, everyone settled in for a viewing of “Planes” thanks to Jim Houdilakus's portable cinema. Young Ryley Bishop, who was the weekend's mascot and champion “wing-walker” was transfixed as Dusty prevailed yet again. The next morning young Riley spent quite some time hanging round Henryk's trailer looking inside, walking round and looking inside again. Finally came up to me and with a cheeky grin asked me if that was Dusty in my trailer?

One of the new elements that evolved this year was the evenings on the field. Rather than packing up and heading off to the pub, a few of us stayed at the field and made good use of the facilities at the Hacienda JaseBro. (I am sure Jason's trailer is a Tardis). Flying till after sunset and setting in for an evening of great food, fine company and where long stories were a-plenty. There is something magical about that big open space at night as well.

It's a privilege that we are given these facilities to use each year. The Jerilderie Shire and all of the people in Jerilderie make us very welcome giving us full use of such a great set-up. Special

Gregg Voak and Ryley

thanks to David Tamlyin from the Shire for making it all available and making sure that the field was ready for our arrival.

Nobody wanted to leave and head back to reality.

Thanks to all those that came – and I hope we did not miss anyone:

Gregg Voak	Antares, Duo Discus, Extra 260
Martin Simons	Golden Wren, Weihe
Leon Carlos	WoodStock, Birgfalke, Fafnir
Rod Watkins	Mx2, Ventus 2c, Minimoa
Caroline	Antares
Jason Sagaidak	Yak 54, Pawnee, ASG 29, ASW 27
Morgan Hill	Grunau, ASH 31
Henryk Kobylanski	Yak 55sp, Antares, Cessna (Dusty's cousin), DG303, SZD 54
Mark Doyle	Reheir, Ventus 2c
Joe Rafenaet	ASW 22, ASH 26
David Millward	Discus 2c, DG1000
Kevin Jolly	Antares
John Copeland	ASH 26, Fox, Wilga
Colin Boothy	K8
Jim Houdelakus	ASG29, Duo Discus
David Hobby	Extra 260, Pawnee, Ventus 2c, DG 600, K8
Simon Bishop	DG600, Extra 330, Ventus
Theo Arvanitakis	Extra 260, Pilatus B4
Chris Carpenter	ASH 26, PSW 101, Pawnee
David Raccanello	Radian
Chris Graham	Blanik
Ross Biggar	Arcus
Wayne Jones	Fauvette, LS4
Dave Bell	ASW 27, DG808
Gary Whitfield	ASW 28, Hots Special
Darrel Blow	Lunak, ASW 28, Ka8
Ryley Bishop	Mascot & Wing walker
Warren Edwards	Photography
Sandra Voak and Roseanna Millward	Moral Support

The following pages are filled with other images from this event.

The full gallery from the event is available on the Oz Scale Soaring Website: http://www.scalesoaring.com.au/

Gary McDougall's scratch built Minimoa going for a walk


ANTA


SP-8013


D-ANHK
HK


DUO
D-1493


VH-DES
Red
Blanik
VH-DES

Rod Watkins' Minimoa

Gary McDougall's Minimoa


D-1493

Review

ST-Model DG-1000 RR

Dan Ouellet, dan@danosoft.com

The ST-Model DG-1000 is a 2 meter scale rendition of the DG-1000 sailplane. It features easy assembly, high aspect ratio airfoils, and a Retractable Motor System! It even has enough power to allow it to rise off the ground from a grass runway!

First Impression

This model looks good, both close-up and in the air! The molding is of good quality. The foam is mostly smooth. There are just a few visible molding marks on the underside of the wings, wing tips and horizontal stabilizer.

It flies well under power, with the RMS fully extended. It becomes a good sailplane when the RMS is retracted. It has a broad speed envelope. This allows it to thermal in light lift, yet speed up for good penetration in moderate turbulence.

The ST-Model, Sheng Teng Electric R/C Model Plane Co., Ltd., located in Jiaxing, China, was established in 2000 to produce R/C airplanes made from EPP foam material, which are "convenient" for consumers. This means that their models are affordable, easy to assemble, and have excellent flight performance.

The DG-1000 is no exception. It meets all these corporate goals. Overall, it is fun to fly, and I am having a good time with it!

Unboxing and Assembly

The model arrived packaged in a box that seemed somewhat light. It is adequate to ensure a safe journey, since after unpacking, all the parts looked good. There was no visible damage, warping or dents, on any of the components.

This model requires very little assembly to get it in the air. The servos, servo covers, linkage rods, and control horns are already in place, having been assembled at the factory. The RMS is installed and setup to function out-of the box, using a sequencing board.

The package includes a basic decal sheet, which can be applied in just a few minutes. All that remains to be done to complete the assembly, is to attach the linkage rod to the elevator and bolt-on the horizontal stabilizer with a single screw. Then just mount the wings, install and bind the receiver, and adjust the control surfaces.

The nose compartment is tight. There is just enough room for a small receiver between the servo and battery compartments. Plus, to help stow the antenna, ST-Model thoughtfully molded in a small plastic tube, in the bottom at that location. One of my Spektrum AR600 receivers fits nicely in this area.

My 1300 mAh 3-cell LiPo battery fits perfectly in the molded battery space. I just had to replace the ESC connector provided by the factory with an EC3 connector to match the ones on my battery.

My 1300 mAh 3-cell LiPo battery fits perfectly in the molded battery space. You can see the clam-shell doors for the RMS at the wing trailing edge.

As to the "red" on the tips and rudder, I just think it makes the model look cool!

This setup worked just right. The aircraft balanced perfectly on the recommended "Centers" of Gravity: 53mm behind the leading edge of the wing with the RMS stowed, and 46mm with the RMS fully deployed. There is no need to add any weights.

Since there is so little to do, the aircraft can be ready to fly in just a few minutes, unless you would like to customize it.

Custom Paint Job

To make the DG-1000 more visible, I painted the underside of the wings and the horizontal stabilizer "flat black." Then I painted the wingtips, rudder and horizontal stabilizer tips "red".

The black bottom really stands out! It helps me to see the model much further out! So far, I have flown it over ½ mile away, possibly as far as ¾ mile distant, without losing sight of it.

As to the "red" on the tips and rudder, I just think it makes the model look cool!

Should you decide to paint yours, note that ST-Model uses "very efficient" mold release compound in its manufacturing process. To give the paint a fighting chance to hold, I found that it helped to first sand the areas to be painted with 400 grit sandpaper, then clean them with denatured alcohol.

The RMS extended and retracted.

RMS Sequencing Board

To better understand how the RMS worked, I read the manual several times.

The principle involved with the RMS is mechanically similar to how a retractable landing gear operates. However, there is a little more going on than that, since in addition to the folding arm, there is a motor and a propeller to account for. To make things simple, ST- Model wires in a sequencing board, which allows the use of a simple 4-chanel radio transmitter to operate the RMS from just the throttle stick.

Unfortunately, this did not work in my case. I ended up removing the board and configuring a custom programming mix.

Custom Programming

The problem I encountered using the included sequencing board, is that try as I may, I could not get it to power up normally. It kept showing a rapidly blinking light. According to the instructions, this indicates "not enough current to power up." The manual suggests to use the throttle trim to increase the current to the board. However, the throttle must also be below its 24% travel setting, or the ESC will not arm. This combination just would not work with my setup.

Therefore, I decided to remove the sequencing board from the model, and

Close-up of the extended RMS.

create my own custom mix to control the RMS in the DX8 transmitter, using the gear switch.

The first thing I did, was assign the throttle cut-off function to the gear switch, so that when I select retract, the throttle will be completely "off." This is done to prevent accidentally powering the motor when the mechanism is stowed. Then I programmed in a two second delay on the RMS (gear) servo, to slow down the deployment and retraction of the mechanism.

The way I use the system to deploy the RMS is by selecting "gear up" on the gear switch to extend it, then count 3 seconds to make sure that the RMS is fully extended, and then power up using the throttle normally. To retract the unit, I do the opposite. I make sure that power is "off" using the throttle, count 3 seconds to allow the motor/propeller to slow down, then select gear retract with the switch.

The two second RMS servo delay not only provides a smooth deployment, but also proved helpful one time as I accidently hit the gear retract switch while the throttle was in the "full open" 100% position. The RMS unit stowed normally without any incidents. Still, just to make sure, I prefer to manually count 3 seconds between using the switch and the throttle.

For the following two mixes involving the use of the motor, I was not sure of the required settings and used my best guesses:

Considering that the propeller trust line is "way above" the centerline of the model, I expected a noticeable nose down tendency, whenever applying power. Therefore, I configured a 23% up elevator mix, to the throttle movement. This looked to be just about the right elevator deflection when applying power!

The propeller is otherwise functioning in a conventional manner. This means that I expected conventional p-factor and torque – a left yawing tendency with the application of power. To compensate, I dialed in a 25% right rudder mix, to the throttle movement. This mix should be most beneficial when climbing at full power.

The clam-shell doors open, the RMS rotates upward and forward, and the motor starts. Reversing the procedure creates a clean rear fuselage and , making it more of a sailkplane than a glider.

Since I like the radio to do as much of the work as it can, I configured some additional mixes. To help control the landing approach, I configured the wing with dual aileron servos and setup spoilerons on the 3 position flap switch. The 1st position is programmed for normal ailerons, the mid-position is set for 35% up on both ailerons, and the 3rd position is set at 75% up. To minimize abrupt changes when deploying the spoilers, I programed it in a slower 2 second servo speed. To assist with coordinated turns, I set up a 55% aileron to rudder mix.

The manual only suggests maximum control surfaces deflections. It does not recommend any dual rates, or exponential settings. To archive a smother flight, I configured dual rates, and dialed in a lot of exponential. The full rates is set to 100% travel on all servos, with 40% exponential. The low rates is cut down to 80% on the ailerons, elevator, and the rudder with the same 40% exponential.

Maiden Flight

The DG-1000's maiden flight was on Sunday, April 6, 2014, at the Seminole Radio Control Club facility in Tallahassee, Florida. The weather was in the mid-70s, clear sky, with variable wind at 8~15 KTs from the South.

Just for fun, I decided to try to have the DG-1000 rise from the ground in a conventional manner. Therefore, instead of hand tossing it, I placed the model in the center of the grass runway, facing into the wind and deployed the RMS. I slowly added power, and at about half throttle, the model begin to slide forward.

I had good rudder authority so I continued adding power, and the model gently lifted off a few inches above the runway, all on its own. It accelerated nicely while in ground effect, as I continued adding power to full throttle, and maintained its height and direction, all without my intervention.

I commanded a slight nose up. The model transitioned easily to a healthy climb attitude, which it maintained hands off after just 1 click of down trim!

So much for best guesses with the mixes – Sometime when the planets align just right, you get lucky! ;-)

I decided to fly one full circuit to see how the DG-1000 felt under power with the RMS fully deployed.

I turned left crosswind and leveled at a couple hundred feet above the runway.

The DG-1000 maintained level flight with about ½ throttle, so I proceeded to turn downwind while keeping the throttle at the ½ position.

Once established on downwind, the model flew hand off without any further trim.

I turned the model on a close base and reduced power to about ¼ throttle to begin the decent. Immediately, the DG-1000 nosed down and begin to lose altitude quickly.

Note to self: This RMS system is a "GOOD SPEED BRAKE"!

I added a little power to stretch the glide and turned on short final.

This worked well for a short approach!

I flared the model at about a foot off the runway and proceeded to make a normal touch-and-go.

Just add power to go back up! Not something I am used to in a glider.

This time, I climbed the model straight out to a comfortable altitude to test the RMS retraction. I leveled it at about 500 FT and cut the power. After counting 3 seconds, I selected the gear retract switch.

The RMS retracted normally with mild indication of the process. Visually, this was a slight altitude loss as the motor powered off and the "air brake" took hold. This was quickly followed by an increase in speed and the model leveling out on its own as the RMS finished stowing itself. Overall, the model responded nicely to the transition.

It was easy to tell that the RMS was retracted - The model automatically settled in to a good glide and became more responsive.

Shortly thereafter, I noticed the right wing lifting slightly, possibly indicating lift on that side. I immediately turned 90 degrees to the right, and the model started rising in light lift. I established a tighter right turn to get it closer to the core of the thermal, while pulling a little on the elevator to keep the fuselage level. I was immediately rewarded with the model rising faster.

This thing does glide well!

Some additional minutes of flying to get comfortable with the DG-1000, showed me that it can slow down and turn fairly tight, without any bad tendencies, such as tip stalling. However, it prefers moving along at a good clip. This model has a lot of penetration for its size, and will retain a decent amount of energy, if you let it.

It is defiantly more of a sailplane than a glider!

While still high, I tested the spoilerons to find out what to expect before coming in for the next landing. They behaved as expected, without any unwanted characteristics or tendencies, or require any trim changes. It is good to know that the spoilerons work well. However, should the DG-1000 need to come down quickly, just deploy the RMS at partial power. That works better!

The ST-Model DG-1000 sailplane is a model that should be in any aficionados' hangar.

I elected to make a normal glider landing approach. I used the first notch of spoilers on base, and went to full spoilers on final. It worked well enough. The approach was predictable, and the model touched down 30 feet or so in front of me in a good 3-point attitude.

Altogether, my timer showed that I used about 3 minutes of power for the maiden flight. Total fly time was approximately 20 minutes. According to my charger, it put 650 milliamp back in to recharge the battery pack.

Therefore, the 1300 milliamp battery should safely supply about 4 minutes of “full” power – Enough for about 4 one minute climbs to 500 FT.

With a little luck finding thermals, it should be very easy to stay up 20~30 minutes per flight, possibly much longer.

Additional Flights

I flew the DG-1000 twice more that day. Both flight lasted over 30 minutes each. I encountered good lift and was able to perform mild aerobatics using only momentum. The wings have noticeable flex under load but seem to hold up well.

Interestingly, neither flight required any additional trim changes.

Conclusion

The ST-Model DG-1000 sailplane is a model that should be in any aficionados’ hangar. It is simple to setup and a joy to fly! The RMS really makes it stands out at the field! Best of all, it is on sale today at Tower Hobbies for only $124.00!

Test Model Specifications

Wingspan:	2010mm (79.1”)
Length:	970mm (38.2”)
Weight:	750g (36.5 oz.) w/ Battery
Battery:	Turnigy 1300 mAh 3 Cell 20~30C LiPo
Receiver:	Spektrum AR600 6-chanels Full Range
Transmitter:	Spektrum DX8
Sequencing:	Custom mix on DX8
CG:	53mm (2.1”) behind leading edge of wing when RMS is completely folded and 46mm behind the leading edge when the RMS is fully deployed.

Sources

Author:	Dan Ouellet, dan@danosoft.com
ST-Model DG-1000 PnP:	<http://tinyurl.com/plvnbh2>
Distributor:	Tower Hobbies <http://www.towerhobbies.com/>
Manufacturer:	Sheng Teng Electric R/C Model Plane Company, Ltd. <http://www.sheng-teng.com/>

This photo was taken at Las Aguilas Sailplane Club in Caracas, Venezuela. On the ground queue, 4m Baudis Salto, followed by 4m Tangent ASH 26, and last, 3.7m Tangent DG600. In the air, a 5.6m Graupner Discus coming in at a low pass. Salto - Jesus Esteller, ASH - Juan Ramon Brunet, DG600 - Renato De Cecco, Discus - Jose Cruz. Photo by Renato De Cecco. Samsung GT-I9300, ISO 50, 1/614 sec., f2.6

CEWAMS

Chris Erikson's Wild Arsed Mountain Slopers

Saddle Mountain Slopener, April 2014

Philip Randolph, amphioxus.philip@gmail.com

Frustrations are the rent one pays to life, worth it, for those who like being alive. And we who like being alive are a sample biased by Evolution, which favors entities that attempt to stay alive, probably imparting the innate enjoyment of it all as sort of a cheap-shot bio programming incentive to not playing lemming.

But as I was saying, somewhere back there, and in case you have already forgotten: Frustrations are the rent one pays to life. Applied to the arcane hobby of throwing toys off ridges, frustrations are the minor costs of dealing with the persons (as corporations are, according to our Supreme Court) who sell us our toys, and who sell us the pieces with which we assemble our toys. It's part of the hobby. One takes a little of the questionable with a lot of the good. And thus it behooves us to gracefully accept a little frustration in our progress toward the greater enjoyment. I have not always been graceful in my acceptance. That's another story, and embarrassing, so I won't tell it. Here I will merely grumble a little, in what I am hoping to pass off as good humor.

Most of this article will merely be a slope report. But I'll start with what mostly doesn't get written about, the grumbles within getting ready to go. And how a goofy HobbyKing switch caused me to test (and crash) an odd plane that had been hanging from my ceiling for five years. Some of these outfits could use a retiree from the Gong Show as BS Czar.

Title page image: Damian at Sentinel, looking north across lowered Wanapum Lake & sandbars. The local growers had half their crops covered in plastic.

Slope Report Part One: Preparation Grumbles

So I'm getting ready for the slopener. I put all my old NiMH batteries in a pile and cut the leads off. One of the guys on the trip, Erik Utter, has great luck with NiMH. He uses a Triton charger. He says he treats his batteries "poorly." Or, "Like dog meat." Darn. I can't remember his exact expletive. He always charges at a high rate. Never has problems. Me, I have lost planes to false NiMH charges. So I'm sticking with NiCad, LiPo, or LiFe.

I have two foam chevron flying wings I'm getting ready. One is my old 48" Sonic. And I've mostly put together a 60" Scout Bee. I've equipped it with a big NiCad. In each I've stuck a $5.75 Lemon 2.4 GHz receiver. These are great for slopers because they don't have fancy failsafe programming that will keep on sending a signal to a servo on loss of signal. That means standard lost model alarms work with them, unlike with a lot of 2.4 receivers. The weak point is just that they sometimes die if you put the battery plug onto its pins backwards. At six bucks that's just cheap instruction.

I put HobbyKing combo switch/light/charge-jacks into the Sonic and the Bee. Then I'm ready to cover the 60" Bee. I decide to charge it first. Which is when I discover the charge jack has male pins. That's backwards from normal battery connections, where charge receptacles have male casings and female pins. Phooey. So I soldered up some backwards charge leads. And that allowed me to charge the Sonic. But I was not going to bury a bogus switch/light/charge-jack into a new Scout Bee. So that wasn't making the trip. *Bong*.

The solution: I'd been wanting to test-fly a strange model I picked up for free with a broken nose. It's a Jade Shogun, but built with the wings swept forward rather than back. The Shogun was kitted by Richard Jarel, probably sometime around 1990, before he became a model builder for Hollywood. He made the taxis for The Fifth Element. The Shogun was billed as "The Ultimate Warrior," and sported USAF markings. I'm not generally into the military stuff, but I liked its lines. Mostly. It came equipped with huge horizontal faux air scoops, that just looked draggy. So I filled them with foaming polyurethane, and patched on a nose out of Kevlar and EPP foam.

It looked like Frankenplane. And then I lost the cockpit cover for a couple years. Found it again in a box of foam rubber. Oh, yeah: It's built of thin plastic, with balsa-covered white-foam wings. Really brittle. Dumb to take to a rocky site. So I decided to haul it along.

The price one pays when one gets those great deals from HobbyKing is that occasionally something is not right. Like one of the LiPo batteries I ordered. Somewhere in the fine print or the picture it probably explained it only had a charge lead, but no power plug. Oh well, it was cheap. Or the latest frustration with their order fulfillment: Back in mid-March I ordered from the International Warehouse, all stuff supposedly in stock. In the second week of April I asked where the stuff was and was told it was held up because one item was on backorder. I grumbled, "Your mistake. Delete that item and send the rest fast, free shipping, by air mail." A few weeks later I said, "Where's the stuff?" They said, "Like you asked, we sent it airmail. Via Malasia Air. It should be there within 45 days." What? Oh, and they did charge me for the shipping. What? Yep, at the bottom of the shipping confirmation it says, "45 days." I grumbled. Pointless. "Oh sir, we appreciate how you feel." I resigned to waiting another month. It arrived that afternoon. Then I tried to order a charger and the site kicked me into something called PayDollar which wouldn't talk to my bank. Gawrd.

But every time I say, "I should just deal with domestic suppliers" I recall Horizon Hobby. I ordered a micro E-flight ASK-21. I was hoping it would be a bit like the Liftworx Seeker, a great tiny light-air plane, but it appears Horizon designed more for scale appearance than aerodynamics. Oh well. It was impossibly inexpensive after a reduced price and crossing a free-shipping threshold. But: We got it out to a field. Bound it to my transmitter. The ailerons would go up and down together, like flaps. An electronics buddy and I spent a couple hours trying to figure out the transmitter programming mistake. Read the little manual. Now, you'd think a manual written by native English speakers would explain, "If the ailerons go up and down together, call Horizon." You'd think that they'd mention that the two aileron servos are linked by a mixer in their control board, and run off one channel in the radio. That means that even when the transmitter says that left and right ailerons are moving in opposite directions, since they're both controlled by the left aileron channel, trying different programming won't fix anything. I called Horizon. They sent me a little dongle that reprogrammed the tiny onboard chip to move the ailerons correctly. I grumbled about the incompleteness of their manual, to no avail. *Bong*. Oh, well. Whoop-te-do. I brought the ASK-21 along, in case winds were rising up the draw at our grassy, Saturday night/Sunday morning 'cow corner' campsite. Nope.

Plus there's my JR 9303. Made by techies for techies. That means goofily *Bong* complex. I vaguely understand that the programming of other transmitters of similar capability is more straightforward.

Slope Report Part Two: Slope Report

In which we are chased off a ridge by lightning (though it was almost time to go anyway)

I had planned to leave Friday, May 25, at about 3:00 pm. I'd drive east across the Cascades and get to Saddle Mountain about 5:30 pm. As it was, I left at 5:30. Then I stopped to socialize for twenty minutes near Issaquah, which turned into two hours, so I arrived at the campsite after 10:00 pm.

Our favorite campsite is up against a bunch of basalt columns overlooking Wanapum Lake, a damned part of the Columbia River. (Woops, post writing I caught that. Dammed.) The guys had a fire going – Chris Erikson and his sweetheart Melissa and his brother Sean, Damian Monda, Erik Utter with four-year-old Cole and ten-year-old Riley, and Mike Zanol. The usual fire chatter.

The next morning Steve Allmaras and Chris's father, Erik Erikson, showed

CEWAMS founder Chris Erikson and the Deathmobile, a 1970 Datsun 510

up. Chris has set up his sun scope. Someone comments on a scrape on my head. Damian asks what kind of a hat I'm wearing. I say "It's a Filson. I found it in the remains of oour 26' geodesic dome that blew down this winter, up on Waldron Island, in the San Juans, when we were doing demo. Geodesic domes were Buckminster Fuller's revenge on hippies. I've been leaving it in the sun in my kitchen window because it smelled a little of mold. But I'm sixty-five, so I can smell a little moldy if I choose to." Sean says, "It's not an option." Slam dunked. Gud shot.

Breaking camp, Mike Zanol says, "Has anyone seen my water bottle? I have the cap." It's a gallon water bottle. I'd grabbed the nearest thing, pretty late, to hydrate, as I headed for my

Desert flowers; Arrowleaf balsamroot, flox, sage

Melissa, Erik E., Steve, Cole at the "Cow Corner" campsite

Steve, Damian, Erik, and Chris launching his EZ Glider

truck and sleeping bag. I say, "I have it. I used it for a pee bottle." Quoth Mike: "So where's Sherman?" For you young persons, that's a reference to Mr. Peabody and Sherman, of the "Bullwinkle Show." Gud Gawrd, Michael.

We drive past boat ramps, their lower ends fifteen feet above what remains of Wanapum Lake. By noon we're at the Mattawa taco stand, where I ordered Lengua tacos. Tongue.

Someone is joking about CEWAMS' lack of formal organization. Damian says "We should have a board meeting." I say, "I met with the board last night. It was a 1x4. When I fell across the wood box." Erik U. says, "That explains the cut on your head." Uh, let's just say it was dark and I tripped.

And then up to Sentinel. Sentinel is 1400' above Sentinel Gap, where the Columbia cuts through the ridge called Saddle Mountain. It's a choke point behind which the ice age floods which scoured Eastern Washington (back when it wasn't called that) backed up to reiteratively create Lake Lewis.

The winds were variable out of the SW. Immediate scent of sage. Half clouds, half sun. We're looking north at the lowered levels of Wanapum lake, great sand bars usually covered by water. It's looking a bit more like a river than usual. The Columbia River. Wanapum is the dam with the 65' crack in a spillway. They dropped the lake 26' to reduce pressure on the dam. They plan to lace it back together with big cables down into the

Looking south from Cow Corner past Damian and Erik to the Columbia river and the Hanford Reach

bedrock. Maybe it will look like Mother Hubbard's shoe.

Damian is first up with a 60" Bowman Hobbies Javelin. That's a 60", standard tail, EPP foam plane. He is on his third set of wings. He cut the 2nd and 3rd sets with a hot wire and templates. We watch his plane circling above the rocky point and its sagebrush. Chris has good flights with his EZ Glider, equipped with flaps. Erik flies his new Herring. Steve zips around with his Bowman Hobbies Super-Scooter and a Boomerang. I get my Sonic up. From across the river to the southwest we hear the Army blowing things up in its Yakima Firing Range.

Erik E: "Why are clouds flat on the bottoms?" A discussion of dew points. Philip: "Because dew points are horizontal." Well,

Erik Erikson and the Cow Corner camp spot

Philip with Franken-Shogun about to smash it on the rocks at Wahatis

Steve with busted-nose Super Scooter

it's actually isotherms which are horizontal. Nerd stuff.

Every once in a while everyone drops out of the air. I mean, our toy gliders drop out of the air. But since we're into vicarious flight it seems like we fall. Lift is intermittent. We wander back to where the guys who only fly beers are.

Sean is stretched out on a fair-sized faux Persian carpet. Folding chairs all around. Erik E. shows me Glacial Lake Missoula by David Alt. He's a geologist. Great maps of how this area was ripped repeatedly by 500 cubic miles of water breaking loose every fifty or a hundred years from an ice dam on the Clark River in Montana. Ice age.

By the trucks Erik blasts rockets off with his kids. Four-year-old Cole gets to push the button on the igniter. 500' up, a parachute, and they send Philip chasing through the sage, sort of an olden retriever.

Back up at the point Steve and I cheat. He lofts his electric Radian, and I toss an electric EZ Glider with a brushless.

Around six Mike and Sean leave. The rest of us head back down toward Mattawa, where it would have been good to get the smallest-fry into a regular bathroom. Oh well. We drive twenty highway miles east and then back up on to Saddle Mountain ridge a few miles East of Wahatis Peak. I'm last there because I did stop in Mattawa. By the time I get there Steve has shoveled clean the campsite we call ‘Cow Corner.’ It’s in a little draw looking south across where the Columbia meanders across the Hanford Reach. Gorgeous view, with the Hanford Nuclear Plant in the distance. Melissa says, “I generally don’t want to camp in view of a nucular plant.” She reluctantly admits it’s kind of pretty. Damian sets up tripods topped with stereo speakers powered by a big amp and a car battery. Some kind of hilly-billy tunes. Everyone cooks steaks. Fire. I go to bed by 10:30.

In the night I wake to light rain on my truck canopy. And I hear coyotes. I get up to put my planes under the truck. Because of the rain, not the coyotes, though I have heard coyotes take an interest in planes. That was back in 2000, kayaking on Wanapum lake. California bighorn sheep herds rumbling by in the night, beaver, otter. A girlfriend and I were camped at Whiskey Dick Creek. A few A-6s from the Whidbey Island Naval Base came winding down the river, between the cliffs, making big noise. The coyotes across the river howled back at them. Heh. Tonight’s coyotes turn out to be Cole crying. Something about the rain on the tent where he sleeps with Riley. Erik takes him into his truck.

Breakfast. Plenty of time to remove an old 72 MHz Rx from FrankenShogun and stick in a Lemon 2.4GHz. I fool with the programming.

Wahatis peak. We generally fly on a south-facing point a few hundred yards east of the peak and its cell towers. But the wind is shearing from the southwest. It’s blowing hard, gusty, and cold. It’s a second jacket, long underwear, and tuck-the-pants-into-the-socks day.

The planes stay up. We fly to the right side of the point, in a big bowl. Chris flies his EZ glider. Steve, his Super-Scooter, Boomerang and a 60" Lumberjack. Damian flies a 48" homebuilt delta. Good flights.

I’m determined to fly my FrankenShogun. Steve throws it for some tests, back in the flat where the sage is forgiving and there are few rocks. It wants to nose under. I add weight to the nose and give it more up. A thirty-foot flight into the wind. Seems good enough. Steve launches it from the rocks at the lip of the bowl. Probably turbulence, but it dives straight down, nose in. It and a couple chips cartwheel thirty feet off to the right and downwind. Phooey.

Oddly, for something so fragile, it’s hardly damaged. Two chunks of the right wingtip have broken off. I can glue them back on with Gorilla glue mixed with a drop of water, which will foam to fill any voids. I’ll find a grassier spot to trim the thing. FrankenShogun will fly again. It won’t look much worse than it already does.

Chris says, “Why don’t you throw something made of foam?” Yeah, of course. My Sonic, dependable, flies great. So does Steve’s Super Scooter, till for the second time in it’s history its nose gets crunched. He gets out the 60" Lumberjack. For some reason it wants to do the same nose dive as my Shogun. Being EPP it survives to fly quite elegantly.

We have about five planes in the air. There is a large black cloud slowly moving toward us along the ridge, from the west. Hail is bouncing off my sunglasses. Erik says, “Was that the Yakima firing range?” Steve says, “I think it was thunder.” Chris says, “Naw. It’s probably the firing range. We were hearing them all day yesterday.” The debate continues till we hear an extended peal. The black cloud is getting closer. We start to see small flashes. Steve says, “I hear lightning can strike from ten miles away.” Erik says “I hope the lightning will hit the towers on Wahatis instead of us.” I say, “Maybe it’s time we got off this ridge.”

Within a few minutes all of us are landing our planes. We all overmisunderestimate how far back the wind will sweep us. Steve, Chris, and I all land within twenty-feet of each other, seventy yards back on the flat.

Cole and Reily with Philip's Sonic and Steve's Super Scooter

Erik & Damian and a couple of cell towers. Looking ENE at Wahatis Peak

As we leave, the hail cuts loose. Within minutes the dirt roads are peppered partly white. A mile east and we are out of the precipitation.

Now, finishing up. A world without coincidences would be so statistically improbable that it would make me believe in a higher being. Perhaps one who had flunked statistics.

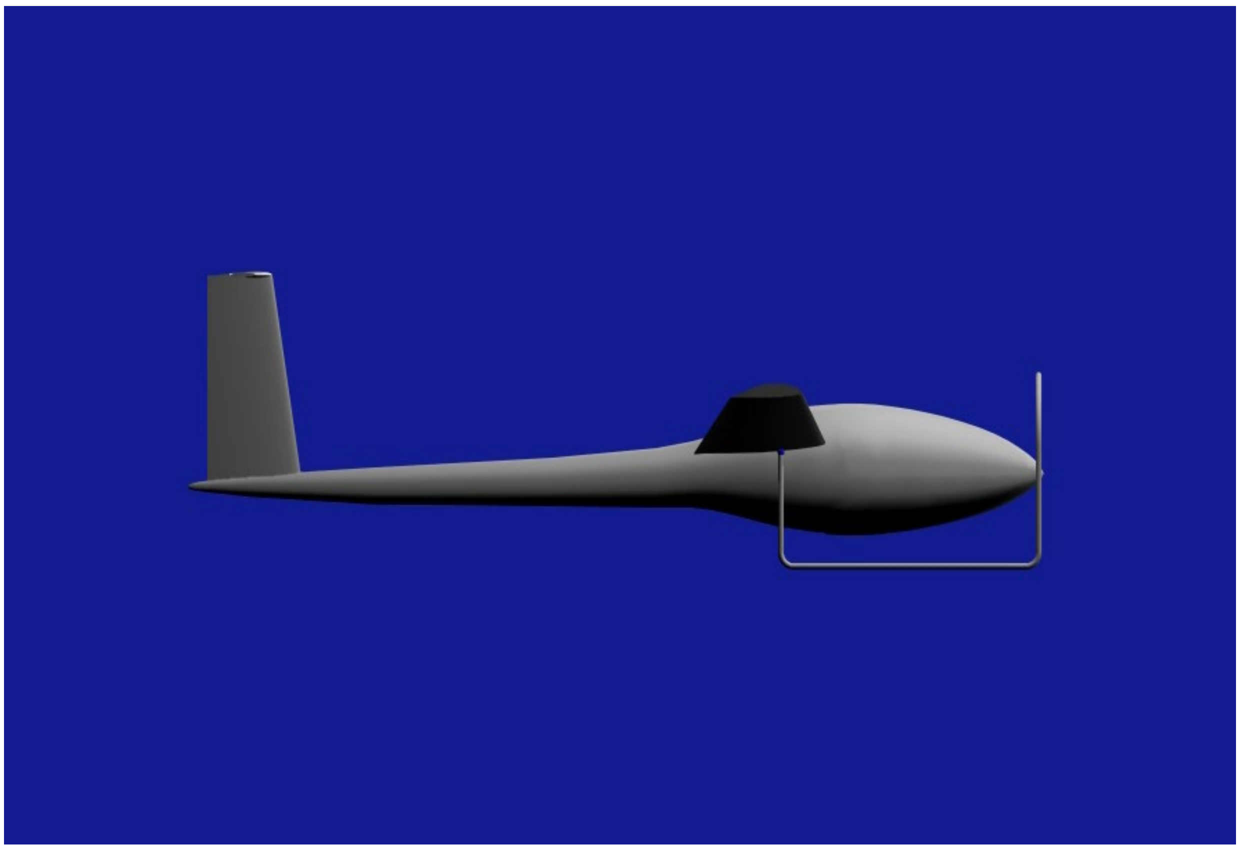
Final quote: "It was scary when I saw this guy charging around the corner at me."

Leaving for a slope trip last year I had gotten as far as the Cle Elum Safeway. That's about 80 miles out of Seattle. I was off at the end of the milk and cheese-fude isle when all of a sudden there is this big bearded guy in a camo jacket and hat charging his cart straight at me with a glower on his face. It was scary but I acted like nothing was out of the ordinary. Then I recognized Damian. So we laughed. Well, here it is a year later about half-way back from Saddle Mountain, and I'm getting decaf in the Cle Elum MacDonalds. I'm waiting at the counter, which is arranged so that I can see through the drive-in-window. There's Damian, in his truck. I try to get his attention, but that's not happening. So I go outside and do my scariest charge around the corner straight toward the hood of his truck. After recognition and the adult guffaws that substitute for little-girl giggles, insert the above quote here. I remind him of when he charged me, in the Safeway. He was stopping for real coffee. We talk about setting up the next trip.

TOM'S TIPS

Large scale CG balancer

Tom Broeski, T&G Innovations LLC, tom@adesigner.com



Here's a simple CG balancer for large scale planes.

Place under the plane and push down. Lets you lift plane from ground, rather than having to lift plane by hand and then setting it on something.

I used 1/2" aluminum rod, but you can use a pipe and "T" rig also. Works great.