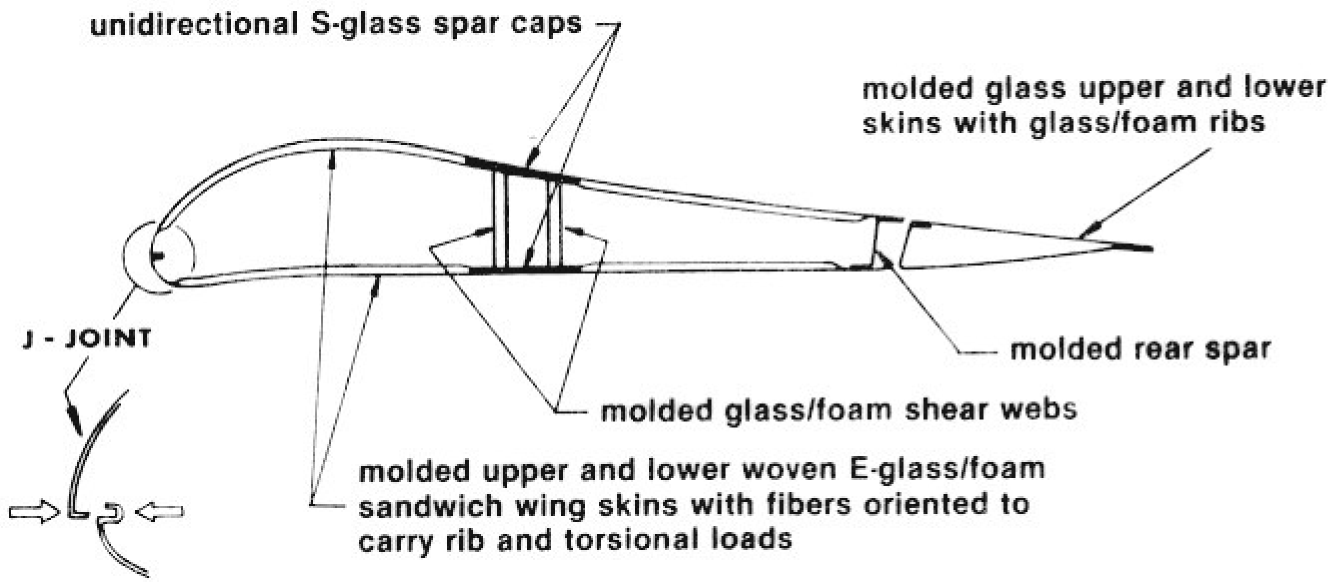
No. 325 JULY 2013

T.W.I.T.T. NEWSLETTER



From Syd Hall's package. Minibat Construction is basically similar to current glass super ships, i.e., a double walled composite monocoque utilizing E glass skins, S glass spar caps and a pre-formed PVC foam core. See above.

T.W.I.T.T.
The Wing Is The Thing
P.O. Box 20430
El Cajon, CA 92021

The number after your name indicates the ending year and month of your current subscription, i.e., **1307** means this is your last issue unless renewed.

THE WING IS THE THING (T.W.I.T.T.)

T.W.I.T.T. is a non-profit organization whose membership seeks to promote the research and development of flying wings and other tailless aircraft by providing a forum for the exchange of ideas and experiences on an international basis.

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Wt/#Issues	FRG	AUSTRALIA	AFRICA
1oz/1	1.75	1.75	1.00
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Meetings are held on the third Saturday of every other month (beginning with January), at 1:30 PM, at Hanger A-4, Gillespie Field, El Cajon, California (first row of hangers on the south end of Joe Crosson Drive (#1720), east side of Gillespie or Skid Row for those flying in).

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PRESIDENT'S CORNER

Just in case you read this section and not some of the editorial comments imbedded in each issue I want to explain what happened with the June issue. You may have noted that the cover showed #324 was the July 2013 edition when it should have shown as July 2013. Please strike out July and pencil in June so you know the real month for issue #324.

I think we have a good mix of items for you this month. My thanks to Phil Barnes for providing a new paper on Configuration Aerodynamics. This was supposed to be part two of his ESA Western Workshop presentation, which I hope he will provide in the near future. In the mean time enjoy this discussion. I have included enlarged images of some figures since they were hard to read in the column form so turn the pages until you get to the ones you can read better.

For those of you on Nurflugel you have seen Al Bowers message on some NASA interns doing really good research in measuring flying wing dynamics. It is in its preliminary stages and the hope is he will have some of the performance measurements by the time we get to the August issue. He is very excited about this since it may prove some of the theories he has been working on in relation to the Horten designs all these years.

If you have been watching the weather channels summer certainly has arrived with a vengeance in some areas like southern California. I hope you are getting in a lot of good flying.

Andy

LETTERS TO THE EDITOR

(ed. – I made a slight error with last month's issue in that the cover and inside showed it as the July issue when it was really the June issue. So please take your copy and scratch out July for issue number 324 and write in June so you will know which month you really have when going back to it. Issue number 325 is the real July 2013 newsletter. Gavin noticed the error before I sent out the few electronic versions and before I put in the members only section, so they all read correctly. I apologize for the confusion.)

I joined TWITT a few weeks ago but I don't remember what I used as my name or my password for the members section. I have bought the plans for the Mitchell U-2. I'm learning a lot. The more I read, there are many "opinions" on just where to place the elevons with respect to the main wing trailing edge.

1. Who is your expert on elevons.
2. How far from the trailing edge should the nose of the elevon be placed, and how far below, (or how much should the gap be) elevon below trailing edge.

I need help.

Most Respectfully,

Austin Cole
<bakengdeuce@netzero.com>

(ed. – Welcome to TWITT. I noted in my letter to him that the experts on the U-2 can be found on the Yahoo group since the members have just about come across and discussed every issue associated with building and flying a U-2. If any of our group has an opinion on this subject please let Austin know and include TWITT so we can share with everyone. Thanks.)

Hi Bob (Michener),

I tried the URL in your article in the Feb 2013 Sailplane Builder (April TWITT Newsletter) for the Dave Welles reference about the Pioneer 2d performance improvements. My Firefox drew a blank but with the last half removed it took me to the Marske site home page. This does have a short test report on the 2d lateral handling which mentions improvements made to it, but I could not find the performance report with pages 6 to 12. I would be grateful if you can send me a route to it.

Re your other comments, I hope my article in the April 2013 issue has answered some of your lift theory questions, but the attached file has some more detail to elaborate the article.

With regards,

John Gibson
<john.gibson@orpheusmail.co.uk>

Response to Bob Michener queries in Sailplane Homebuilder, February 2013

Finding The Lift Source:

Jim's friend was right in that all aerofoils have about the same basic reaction to AoA, but lift is not created by it. AoA controls the quantity of the circulation that creates lift by modifying the wing surface pressure. It would be impossible to deduce the source of airfoil lift from a vertical dive. The wing lift would be zero (assuming zero tail load), regardless of which part of the airfoil was responsible. Movement of the aiming spot across the canopy would result from drift of the air-mass containing the aircraft in a wind. If "flat plate" refers to the standard chord line from leading edge to trailing edge, that is not the aerodynamic reference datum line which is defined by its alignment with the airstream at zero lift. It was known in the 19th century that curved airfoils give lift when the standard chord base line is at zero AoA. Kutta's thesis showed how a simple circular arc airfoil would do that. His work grew into Glauert's classic 1926 thin aerofoil (i.e. camber line) theory. NACA's families of airfoils from the 1930s and 1940s were assembled by combining standard camber lines with a range of symmetric profiles of various thicknesses to improve the lift range and drag. The published airfoil lift, drag and pitching moment data were measured in wind tunnels, however.

Reflexed Airfoils And Flying Wings:

A reflexed rear portion of an airfoil is just a full span fixed elevator for unswept flying wings. It is just an upside down flap that reduces the maximum lift, and it has no direct effect on stability. However, in the absence of a tail the only requirement for stability is a

CG located ahead of the quarter chord lift centre, which is the same for all airfoil sections. At a chosen intermediate AoA the reflex supplies the necessary nose up pitching moment to counter the nose down lift-weight couple. The adjustment to trim the whole AoA range is applied by a central part span elevator, with a further cost to the maximum lift at full back stick. If a normal camber airfoil is used in the interests of maximizing lift, the elevator would need enough power on its own to overcome the nose down moments of both the CG and the basic airfoil pitching moment with a much larger drag penalty. That is why Jim got a better glider after adding a reflex on the Pioneer, but regardless of reflex or none, flying wings need a larger wing for a minimum flying speed than an aft-tailed design which can fly "clean" with zero tail load and still trim a lift flap.

The central elevator has the advantage of ensuring a wing root stall giving good spin resistance, and I think that at least one of Fauvel designs (from the 1950s, not 1930s) had no tip washout. The leading edge cusp or local nose droop applied by Jim is a common device to tame the stall, especially useful on the 230xx series. These have good lift but a sharp stall with its far forward camber peak (the 2 is the percent camber, the 30 is the percent chord wise peak position, and the xx is the percent thickness.) They have the advantage for flying wings of zero pitching moment.

Chord Wise Thrust:

This is a slightly misleading term because it has a hint of a propulsion force about it, and it is much better to call it by the more usual leading edge suction. Air cannot pull on a surface and suction is just less pressure. The pressures on a wing act normal to the local surface, resolved into vertical lift and horizontal force components. The latter act forwards on the front-facing profile slopes and rearwards on the aft-facing slopes. If air had no viscosity they would match exactly with neither drag nor thrust, or "d'Alembert's Paradox" (1744), a mystery only solved after Prandtl's discovery of the boundary layer (1904). As well as its direct skin friction effects, the resulting loss of energy in the layer prevents complete pressure recovery at the rear of the airfoil leaving surplus pressure drag (a lack of push) at the trailing edge. This effect spreads forwards as the AoA increases, eventually leading to the stall.

However, there is a forwards bending force along the chord line as the AoA increases. Lift acts normal to the flight path, resolving into components normal to and along the chord line. At 15 degrees AoA, the chord wise force is 25% of the lift force, far greater at the maneuver limit speed than the drag components, although airbrake drag can be considerable at maximum speed.

Liebeck:

You seem to have crossed paths with Bob Liebeck at the absolute beginning of his illustrious career at Douglas with a master's degree (1962) and PhD (1968) at the University of Illinois, a renowned designer of high lift single element airfoils (no flaps and certainly no reflex), for many years the program manager of the Boeing blended body flying wing airliner research, professorships in California and MIT, and winner of the 2010 Guggenheim Medal. When his airfoil theory knowledge had advanced, he would have binned his youthful notions of ex-partner molecule reunions and that the two-dimensional airfoil flows can cause a vortex wake sheet. The latter does lead to induced drag, but this needs the three-dimensional cross flows formed on a finite wing with tips and is not present in two-dimensional airfoil profile flow.

However, elements of Liebeck's ideas sketched in your February questions did lead in 1973 to the profile shown here *(next page)*. This had the quite remarkable property of a section lift/drag ratio of 230 at a lift coefficient of 2.18. Extending the upper surface laminar boundary layer as far aft as possible without triggering separation of the turbulent boundary layer to the trailing edge with a steep pressure recovery, it took to extreme lengths the design principles of F.X. Wortmann. The latter was more constrained by the wide low drag speed range demanded for sailplanes, a problem solved by use of a cruise flap to maintain laminar flow on much of the lower surface. (See page 7, February 2013 issue, for Wortmann's 1967 airfoil with a 17% chord flap.)

Liebeck airfoil (1973)

John Gibson
17th June 2013

(ed. – Some of the images may be hard to read in the hardcopy version so I have duplicated those at the end of the article.)

Introduction

This article, excerpted from a larger work in progress, "reviews and renews" the lift and drag of elliptical and trapezoidal wings at subsonic Mach number. The methods outlined are incorporated in "lifting-line" aerodynamic models of the aircraft shown in Figure 1.

Figure 1: Configuration Aero – From the Wrights to the Delta Canard

1.0 ELLIPTICAL WING: OPTIMISTIC LIFT & DRAG

The elliptical wing, hallmark of the famous Spitfire fighter of WWII, does not exhibit the theoretically-advertised aerodynamic performance benefits relative to non-elliptic wings. This of course is a

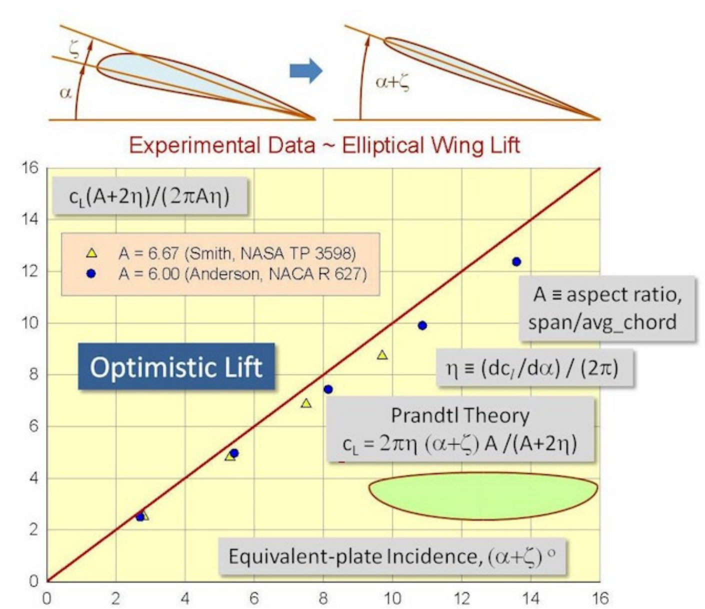


Figure 2: Elliptical Wing Lift – Theory Vs. Data

shortcoming of the theory, not of the wing itself, which served admirably in the Battle of Britain. The theoretical shortfall is substantiated with data by Dr. Sighard Hoerner in his well-known textbooks "Fluid Dynamic Lift" and "Fluid Dynamic Drag." Figure 2 shows that the lift data for two elliptical wings falls about 11% short of the theoretical prediction, and Figure 3 shows that predicted induced drag is 11% optimistic. In both figures we use Dr. Hoerner's style of re-arranging the applicable equation to linearize data. Per Yogi Berra:

> "*In theory, there is no difference between theory and practice, but in practice...*"

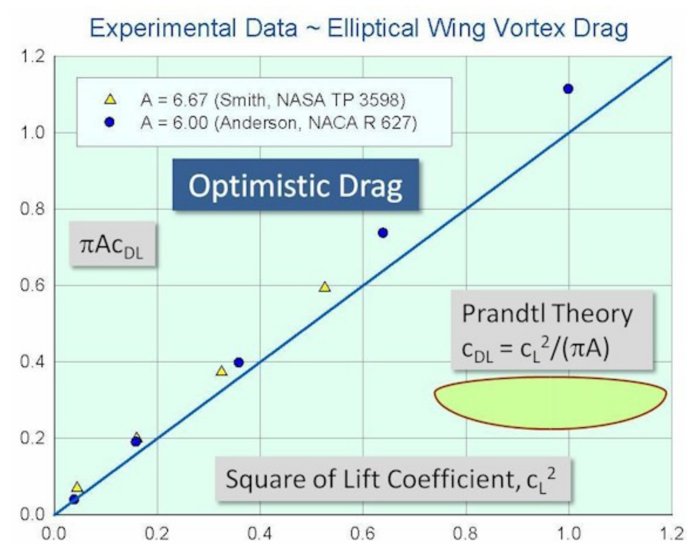


Figure 3: Elliptical Wing Drag – Theory Vs. Data

2.0 LUDWIG PRANDTL & HEINRICH HELMBOLD

Not withstanding arguably small differences between theory and data, Ludwig Prandtl (circa 1918) brought forth a remarkable first understanding of the key principles of finite-wing lift. Figure 4 *(next page)* shows the horseshoe vortices which characterize Prandtl's theory. Whereas Prandtl evaluated the trailing-vortex-induced downwash at the "lifting line" (1/4-quarter chord from the leading edge), Heinrich Helmbold (circa 1940) improved upon Prandtl's theory by evaluating the downwash, due to both the bound and trailing vortices, at ¾-chord.

Although the so-called "3/4-chord theorem" has been deemed "unjustified" by some prominent theorists including Kuchemann and Thwaites, it predicts well the lift and its distribution on any wing. Indeed, Helmbold's lift formulation is the foundation of further lift and drag correlations to be described next.

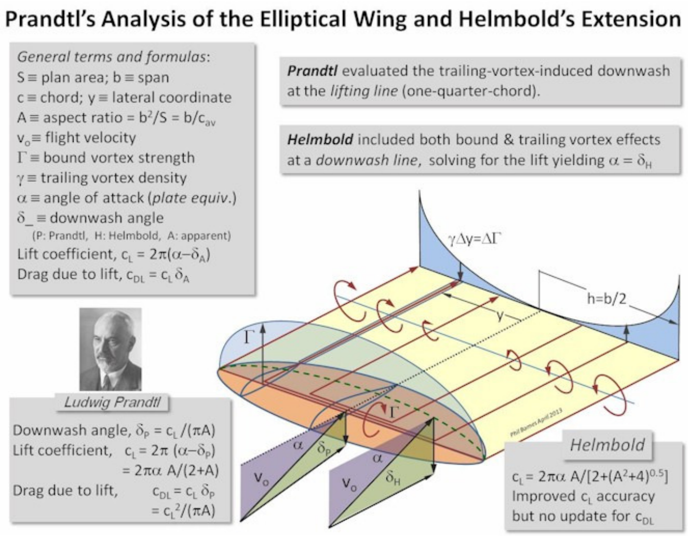


Figure 4: Prandtl's Theory and Helmbold's Extension Thereof

3.0 HELMBOLD, DIEDERICH, & POLHAMUS

Frederick Diederich, a prominent NACA aerodynamicist, extended Helmbold's approach to include swept wings. Diederich introduced a "normalized lift slope" and "equivalent aspect ratio" with which the lift-slope data for a wide range of wing shapes collapses largely to a single curve. The *Helmbold-Diederich Condensation*, using aspect ratio (A), mid-chord sweep ($\sigma_{c/2}$), and streamwise section lift-slope efficiency (η), aligns with the theoretical prediction of low-aspect-ratio-wing lift by famed NACA aerodynamicist, Robert T. Jones.

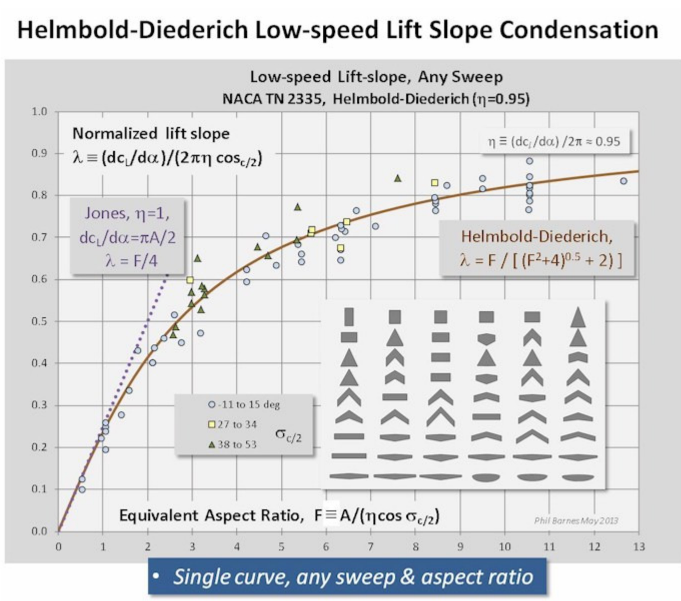


Figure 5: Helmbold-Diederich Low-speed Lift-slope Condensation

Another prominent NACA aerodynamicist Edward Polhamus, introduced an alternate correlation (Figure 6 – next page) of the lift slope (normalized to the "Jones-extrapolated" lift of Figure 5). The *Helmbold-Polhamus Condensation* adds convenient accommodation of transonic effects with the term (A^2M^2), consistent with R.T. Jones' theory which predicts no Mach effect on lift slope as ($A \rightarrow 0$).

4.0 APPARENT DOWNWASH METHOD

In enhancing the accuracy of computed lift, neither Helmbold, Diederich, nor Polhamus updated the drag. We know from Prandtl's work that the induced downwash reduces lift and increases drag by amounts set by aspect ratio. This suggests that either *lift-slope condensation* previously described can be manipulated to yield a companion *induced-drag condensation* applicable for any planform. Toward this goal, we introduce an "Apparent Downwash Method" (ADM) which states: "Given both the incidence and the lift, any deficit of lift from the two-dimensional lift expectation is due to an apparent downwash which, factored by the lift coefficient, yields the induced drag." Figure 7 *(next page)* applies this postulate to yield a term in brackets which represents the fractional amount by which the induced drag is greater than Prandtl's prediction. The corresponding ratio (Φ) thus becomes the inverse of the traditional empirical factor (e). Figure 8 *(next page)* shows that ADM condenses the induced drag reasonably well, provided its curve (dashed) bends to capture R.T. Jones' theory for ($A \rightarrow 0$).

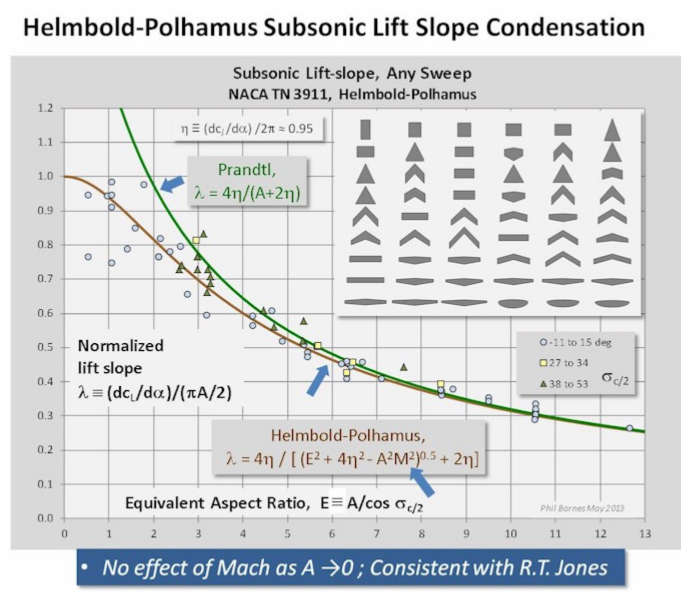


Figure 6: Helmbold-Polhamus Subsonic Lift-slope Condensation

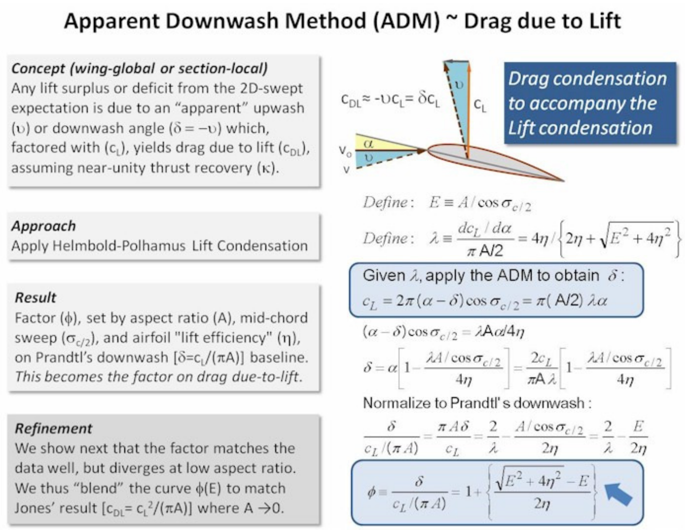


Figure 7: Derivation, ADM Factor on Prandtl's Induced Drag Formula

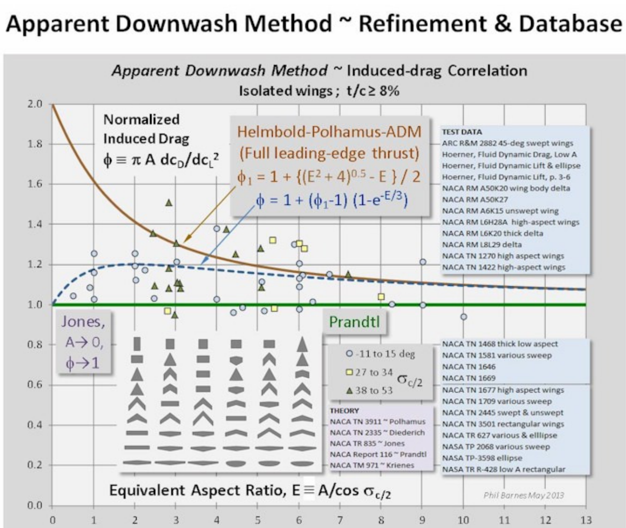


Figure 8: ADM Drag due to Lift, Comparison With Test Data

Figure 9 provides a close-up of the data of Figure 8, but with the wing plan forms replacing the data symbols. The data includes three elliptical wings, each represented by a "flat-diamond" planform. First and foremost, we verify that the consensus of induced-drag data, with or without an elliptical planform, exceeds Prandtl's prediction by about 15%. Second, the elliptical wings exhibit no apparent advantage. Third, we notice that the swept wings of "median" aspect ratio appear to exhibit higher induced drag than unswept wings in the same region, whereas the reverse seems to hold at lower aspect ratio. Overall, taking into consideration the considerable scatter in the test data, the *ADM Induced-drag Condensation* appears to offer a reasonable prediction, provided the wing incorporates airfoil sections exhibiting essentially "full leading edge thrust," as discussed next.

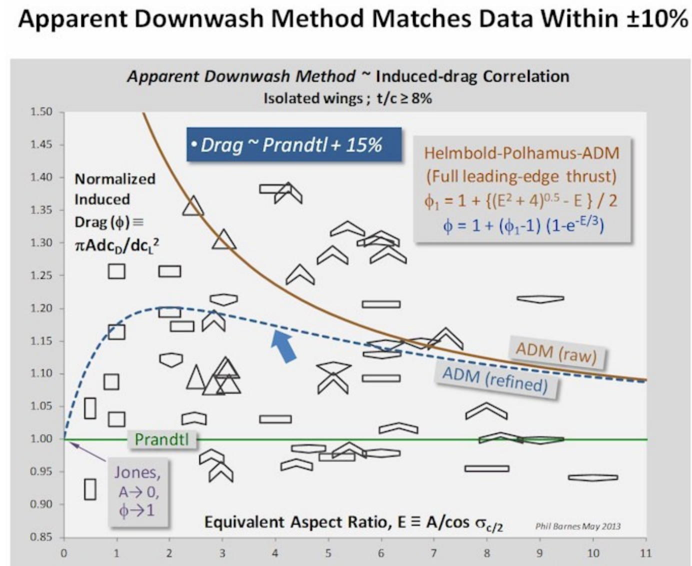


Figure 9: Close-up of ADM Vs. Test Data for Induced Drag

5.0 DRAG DUE TO LIFT WITH THIN & SHARP SECTIONS

Characterizing "3-component" airfoil forces reveals an important phenomenon, that of "leading-edge thrust." Figure 10 shows three forces on thick and thin airfoils.

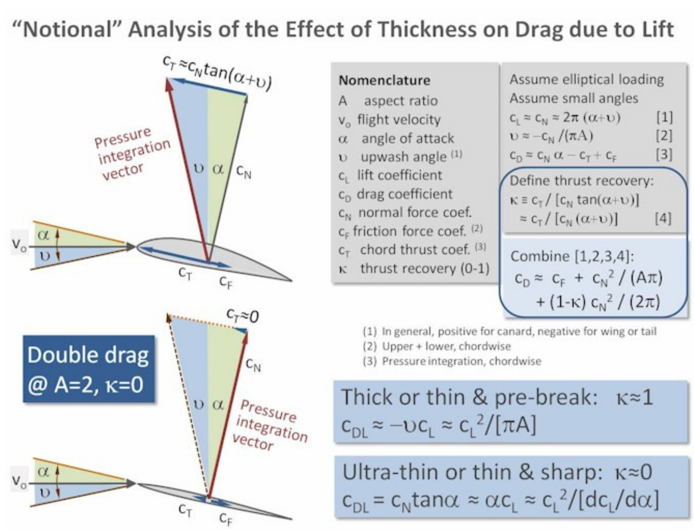


Figure 10: Three-component Modeling of Airfoil Forces

Whereas both the thick and "ultra-thin" airfoils shown develop a similar normal force coefficient (c_N), only the thick airfoil has the chordwise-projected area to sustain a chordwise thrust coefficient (c_T) which, in general, remains proportional to the normal force coefficient over a wide range of lift coefficients. Although the literature often refers to "full suction" or "zero suction" limits on drag due-to-lift, we point out all airfoils have "full suction" (indeed, an ultra-thin section sees the most) whereby "leading-edge thrust" is a more meaningful descriptor.

Overall, Figure 10 shows that a wing with a "thick" airfoil will exhibit drag due-to-lift close to Prandtl's prediction, but a wing with an ultra-thin section may exhibit perhaps twice such drag. We are indebted to Polhamus for first describing this phenomenon. Figures 11 and 12 show applicable characteristics for symmetric airfoils of various thickness. A full correlation of leading-edge thrust, beyond our scope herein, would take into account effects of airfoil geometry, Reynolds number, lift coefficient, and Mach number. However, thanks to the work of Polhamus, we know the upper limit (zero-thrust) of drag due to lift (see Figure 12 for a 6% airfoil). Above the "break" In Figure 11, leading-edge flaps optimally scheduled with angle of attack can much reduce drag.

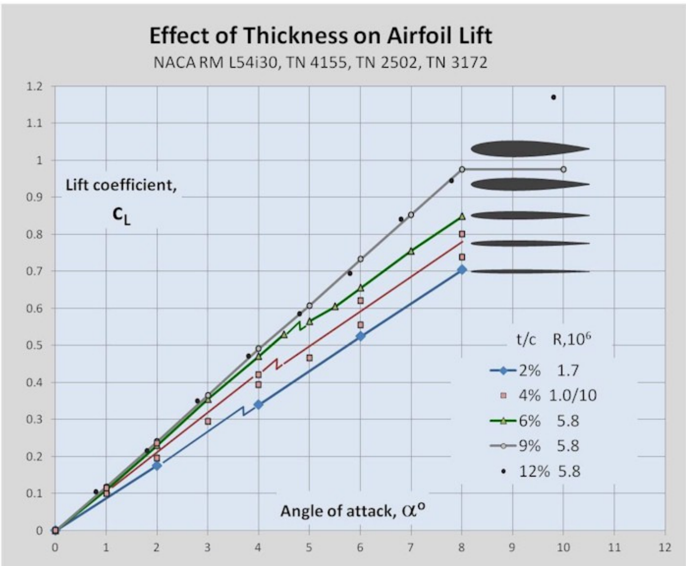


Figure 11: Pre/Post-break Regions of Airfoil Drag Polars

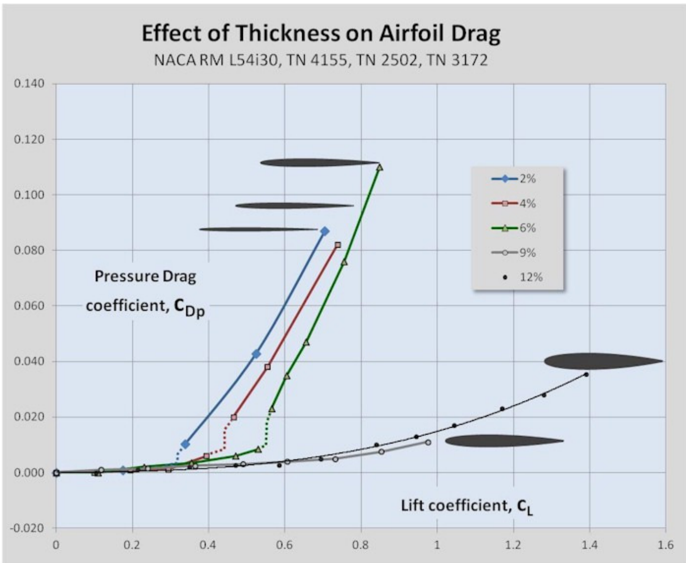
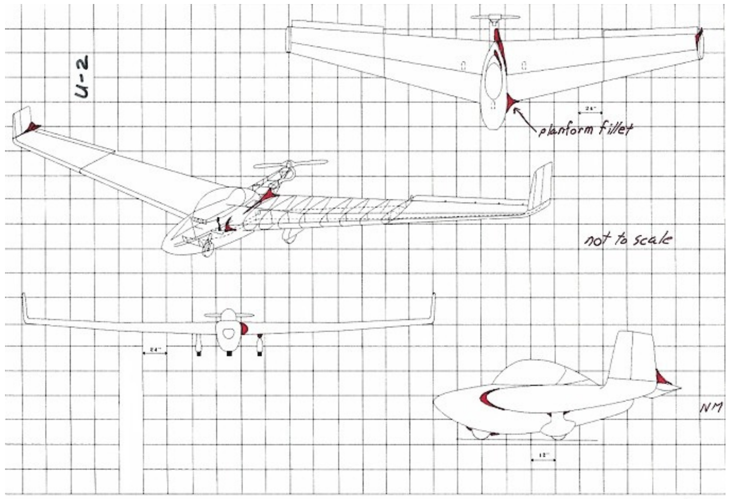


Figure 12: Typical Drag Polar of a 6% Thick Airfoil

Mitchell U-2 Group Threads

(ed. – This is an image showing how some fairings could be added to a U-2 to improve its gliding ability.)



Hi Carol, I am working on an article for the EAA's online magazine, Experimenter. I need hi-res jpg images of your sailplane/motorgliders. Please contact me.

Yours,

Murry I. Rozansky
mirco@jps.net

Hi Friends,

I just received this message *(from Murry)* and am hoping you can help me out. I would like to get more articles and information to the aviation community on the Mitchell Wing so I have been requesting people to write articles for the various aviation magazines that cater to the Mitchell Wing.

Richard Avalon (my husband and last partner of Don Mitchell) used to do this and got free publicity with his articles that he wrote.

Unfortunately my photos are old. I don't have any good ones to send Murry for his article.

Perhaps some of you may have some good high resolution images of the B-10 and U-2 that would be worthy for an EAA magazine article.

I would really appreciate it if you could forward any to Murry and a copy to myself to keep in my records for future requests.

Still not much in the way of blueprint sales. I'm hoping articles such as the one mentioned here will help with that.

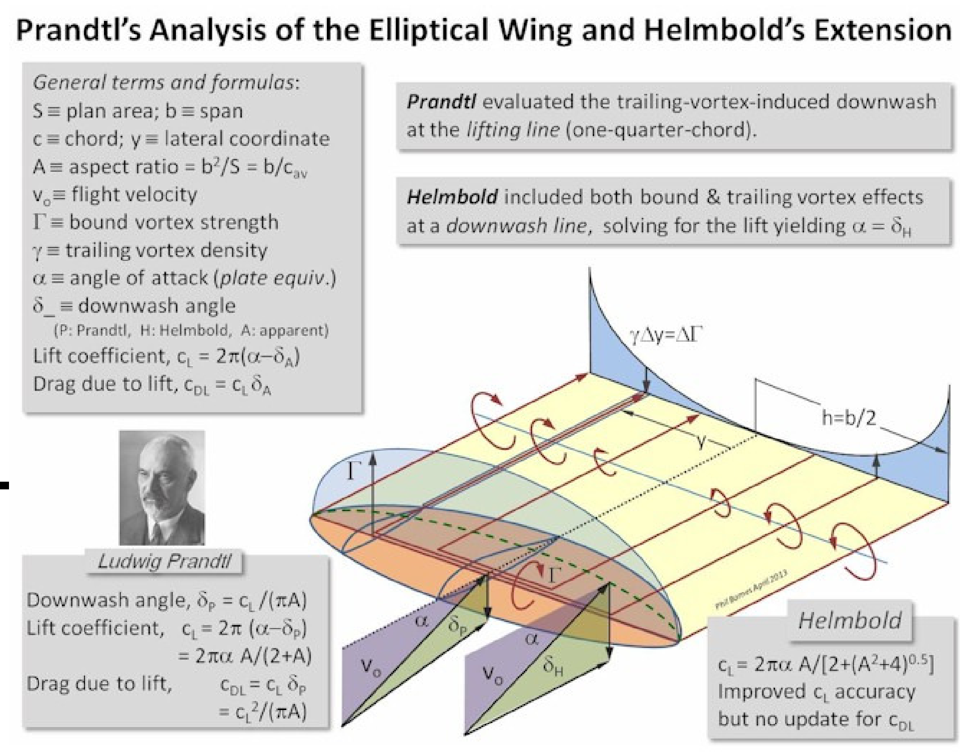
Thanks so much!!

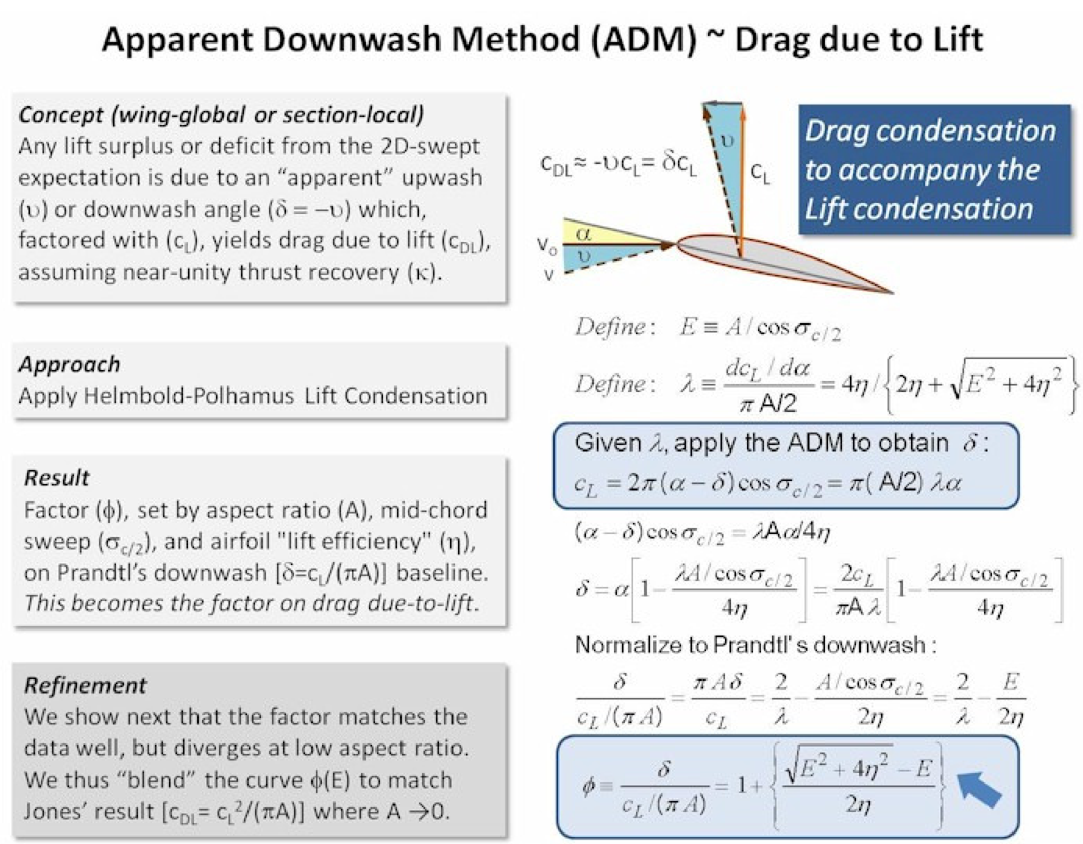
As Richard used to say, Sky Out!

Carol Avalon
<mitchellwing@earthlink.net>

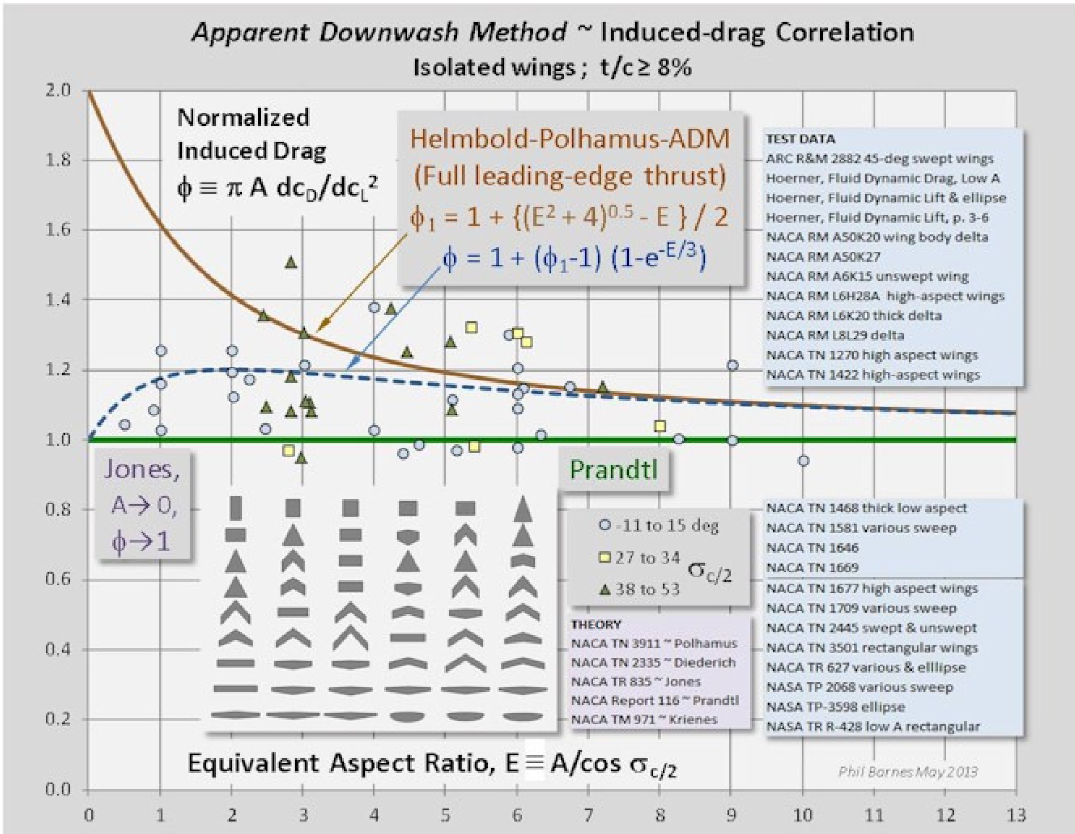
(ed. – If anyone out there has some pictures that would meet Murry's request please forward them to him and copy Carol so she can rebuild her ability to better market the U-2 and other Mitchell designs.)

The images on the following pages are enlarged versions of those that may have been difficult to read the details in the smaller version. I do have the original PDF file of this article so if you would like a copy send me an e-mail and I will reply with it as an attachment.

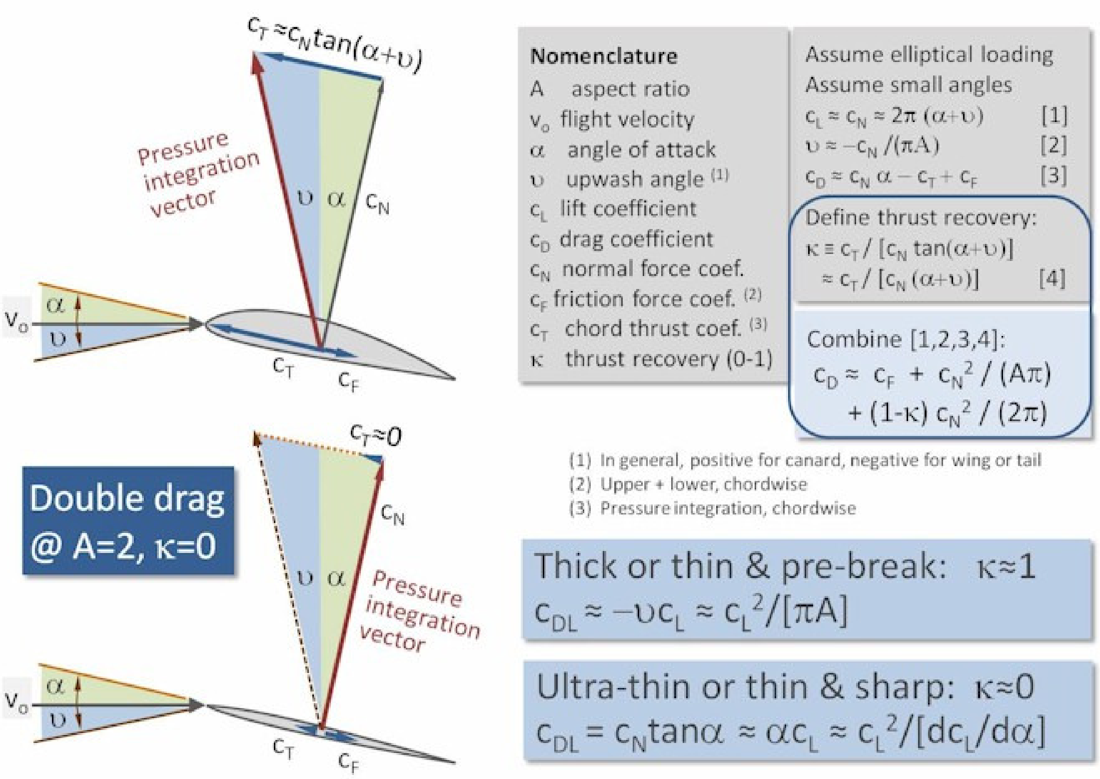




Apparent Downwash Method ~ Refinement & Database



"Notional" Analysis of the Effect of Thickness on Drag due to Lift



Nurflugel Bulletin Board Threads

In a short part of a current Discovery Channel program on "Yellowstone: Brink of Disaster" they focus on a scientist who gets VERY deep in studying the Perigrine falcon, remarkable for perhaps the widest speed range of any avian. Amazing use of x-ray movies, especially in the bird's vertical takeoff aspects. If you can get past the breathless hype, it's an eye opening bit of technological wizardry.

A very short bit in they typical "gee-whiz"; hodge-podge programming, but worth the viewing. I'm sure Paul MacCready would have been enthralled, as would Gus Raspet with his interest in flexible, adaptive wings.

I'd suggest doing a search on your local provider's listings.

Cheers, Bob

Original Message From: Huib Ottens

Since I helped the author Andrei Shepelev writing this book I would like to take the opportunity to advertise the book Ho 229: SPIRIT OF THURINGIA- THE LUFTWAFFE'S JET-POWERED FLYING WING.

If you are interested in the Horten Ho 229 and the story of the Horten brothers (Reimar and Walter) I think you will like this book.

It is published as number 12 in the well-known Luftwaffe Classic series by Classic Publications (an imprint of Ian Allan Publishing Ltd.). The book has a hardback cover and carries 128 pages. At the moment the book is at the print shop with publication aimed for **September 2006.**

Now from Norm Masters: "I was shocked to find out this morning (6/12/13) that this book is already available as a free ebook on http://ebookee.org/ . I know that you and Andrei Shepelev put a lot of work into it and I hope that you got compensated for all the time you put in."

I am a modeler from Poland and need help.

I'm looking for a RC Real Flight Simulator for my son, especially version 5.0 or bigger (for airplanes, gliders and helicopters).

I am looking too for Radio Control System like: Futaba, JR, Robbe, Graupner, Flysky RC or other similar RC System with min. 7 channels and more, new or used in any condition (but will be like every others too). Best will be in working condition (eventually for repair) with receiver and few servos, with frequncy.2,4GHz, 35 MHz or 40MHz.
Maybe anyone have radio that are no longer needed and will want help me.
I'll be like too servos, battery, electric motors, maybe modeler magazines in English, German, French, etc.

If anyone has one that are no longer needed and would like help me please and let me know and write to me off-list at e-mail: mnazimek@op.onet.pl

Please write ASAP best in English.

Thanks

Martin

(ed. – There were a couple of replies to Martin's request for information and they only contained suggested websites. Just in case any of you are also interested in these types of equipment or computer simulators, here at the references.)

http://rcflightsim.com/

http://www.rcgroups.com/

AVAILABLE PLANS & REFERENCE MATERIAL

Tailless Aircraft Bibliography

My book containing several thousand annotated entries and appendices listing well over three hundred tailless designers/creators and their aircraft is no longer in print. I expect *eventually* to make available on disc a fairly comprehensive annotated and perhaps illustrated listing of pre-21st century tailless and related-interest aircraft documents in PDF format. Meanwhile, I will continue to provide information from my files to serious researchers. I'm sorry for the continuing delay, but life happens.

Serge Krauss, Jr. skrauss@ameritech.net
3114 Edgehill Road
Cleveland Hts., OH 44118 (216) 321-5743

Books by Bruce Carmichael:
Personal Aircraft Drag Reduction: $30 pp + $17 postage outside USA: Low drag R&D history, laminar aircraft design, 300 mph on 100 hp.
Ultralight & Light Self Launching Sailplanes: $20 pp: 23 ultralights, 16 lights, 18 sustainer engines, 56 self launch engines, history, safety, prop drag reduction, performance.
Collected Sailplane Articles & Soaring Mishaps: $30 pp: 72 articles incl. 6 misadventures, future predictions, ULSP, dynamic soaring, 20 years SHA workshop.
Collected Aircraft Performance Improvements: $30 pp: 14 articles, 7 lectures, Oshkosh Appraisal, AR-5 and VMAX Probe Drag Analysis, fuselage drag & propeller location studies.

Bruce Carmichael brucehcarmichael@aol.com
34795 Camino Capistrano
Capistrano Beach, CA 92624 (949) 496-5191

VIDEOS AND AUDIO TAPES

(ed. – These videos are also now available on DVD, at the buyer's choice.)

VHS tape containing First Flights "Flying Wings," Discovery Channel's The Wing Will Fly, and ME-163, SWIFT flight footage, Paragliding, and other miscellaneous items (approximately 3½+ hours of material).
Cost: $8.00 postage paid
Add: $2.00 for foreign postage

VHS tape of Al Bowers' September 19, 1998 presentation on "The Horten H X Series: Ultra Light Flying Wing Sailplanes." The package includes Al's 20 pages of slides so you won't have to squint at the TV screen trying to read what he is explaining. This was an excellent presentation covering Horten history and an analysis of bell and elliptical lift distributions.
Cost: $10.00 postage paid
Add: $ 2.00 for foreign postage

VHS tape of July 15, 2000 presentation by Stefanie Brochocki on the design history of the BKB-1 (Brochocki,Kasper,Bodek) as related by her father Stefan. The second part of this program was conducted by Henry Jex on the design and flights of the radio controlled Quetzalcoatlus northropi (pterodactyl) used in the Smithsonian IMAX film. This was an Aerovironment project led by Dr. Paul MacCready.
Cost: $8.00 postage paid
Add: $2.00 for foreign postage

An Overview of Composite Design Properties, by Alex Kozloff, as presented at the TWITT Meeting 3/19/94. Includes pamphlet of charts and graphs on composite characteristics, and audio cassette tape of Alex's presentation explaining the material.
Cost: $5.00 postage paid
Add: $1.50 for foreign postage

VHS of Paul MacCready's presentation on March 21,1998, covering his experiences with flying wings and how flying wings occur in nature. Tape includes Aerovironment's "Doing More With Much Less", and the presentations by Rudy Opitz, Dez George-Falvy and Jim Marske at the 1997 Flying Wing Symposiums at Harris Hill, plus some other miscellaneous "stuff".
Cost: $8.00 postage paid in US
Add: $2.00 for foreign postage

VHS of Robert Hoey's presentation on November 20, 1999, covering his group's experimentation with radio controlled bird models being used to explore the control and performance parameters of birds. Tape comes with a complete set of the overhead slides used in the presentation.
Cost : $10.00 postage paid in US
$15.00 foreign orders

FLYING WING SALES

BLUEPRINTS – Available for the Mitchell Wing Model U-2 Superwing Experimental motor glider and the B-10 Ultralight motor glider. These two aircraft were designed by Don Mitchell and are considered by many to be the finest flying wing airplanes available. The complete drawings, which include instructions, constructions photos and a flight manual cost $250 US delivery, $280 foreign delivery, postage paid.

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COMPANION AVIATION PUBLICATIONS

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The purpose of ESA is to foster progress in sailplane design and construction,which will produce the highest return in performance and safety for a given investment by the builder. They encourage innovation and builder cooperation as a means of achieving their goal. Membership Dues: (payable in U.S. currency)

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Electronic Delivery	**$10 /yr**	U.S. Students	Free

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