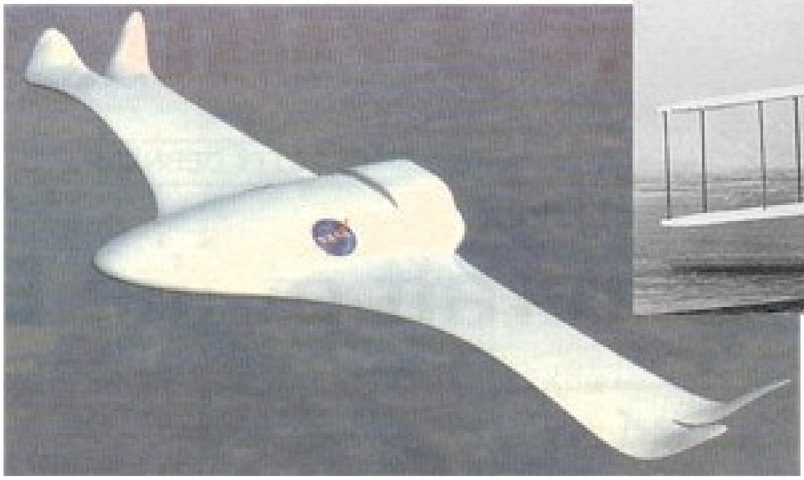
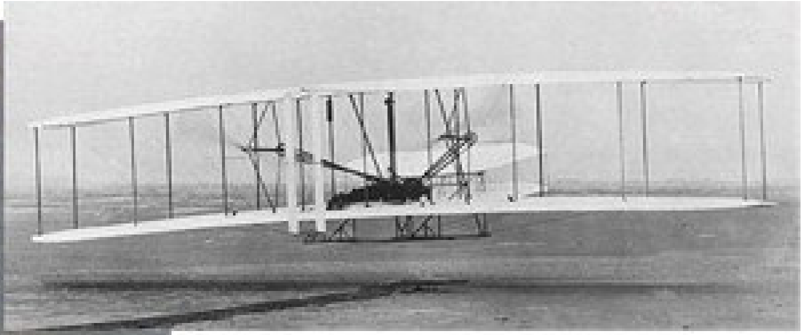
No. 203 MAY 2003

T.W.I.T.T. NEWSLETTER





The evolution of aviation. Left is an artist's concept drawing of what a future plane from the Morphing Program might look like. New materials would allow aircraft to change shape while in flight. (Source: San Diego Union Tribune, May 1, 2003.) Right is the 1903 Wright Flyer making its first flight that got everything started.

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., **0305** means this is your last issue unless renewed.

Next TWITT meeting: Saturday, May 17, 2003, beginning at 1:30 pm at hanger A-4, Gillespie Field, El Cajon, CA (first hanger row on Joe Crosson Drive - Southeast side of Gillespie).

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. T.W.I.T.T. is affiliated with The Hunsaker Foundation, which is dedicated to furthering education and research in a variety of disciplines.

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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).

TABLE OF CONTENTS

PRESIDENT'S CORNER

Where has this year disappeared to so far? I can't believe we're pushing into May already. I hope everyone has enjoyed last couple of month's issues with the material from Irv Culver. We have a lot of it, so I will continue with more of his thoughts on various aspects of flying wing design. I know you guys like pictures and formulas and certainly Irv's work contains it. If you see some stuff repeated it is because he wrote it over a number of years in response to something or someone and obviously had to provide a little background.

I apologize for not having a program for May, but I think we can have some fun sharing various types of models and learning more about each other's interests in aircraft over the years. We will keep digging trying to find a program for the anniversary meeting in July. Don't forget in July we also have cake and ice cream to help us celebrate.

I am looking for new material to add to the web site, either as unique to TWITT or as links to other sites of interest. So if anyone has run across a site they think others would enjoy, please pass it along to me and I will post it on our site.

I have been pleased that several inquiries on membership have come in over the past several weeks. One was from a gentleman in Cordoba, Argentina, and he is working on plans for a model Horten IV that apparently he is developing for sale. Hopefully, he will complete the project in a short period of time and we will be able to purchase sets.

Now that the summer months are rapidly approaching, I am hoping some of you are going to send in some pictures of your favorite model or aircraft flying in the sunny skies of your local area.

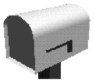
Andy

MAY 17, 2003 PROGRAM

We were unable to locate a speaker for May, so I thought maybe we could have sort of a theme meeting. In this case it will be "Modeling Show & Tell" time. We would like to have you bring your favorite airplane model to the meeting and tell us a little bit about it. These can be flying wings or conventional aircraft, R/C models or free flight, wood or plastic, etc. You get the idea. It should be fun sharing our "toys". Note: If your model is too big to bring along in your car or van, then bring some pictures so everyone can at least see it.

We will have some video footage of seagulls slope soaring off the side of the cruise ship I was traveling on while you were at the March meeting. Some of it is interesting in that you get a good look at how they reshape their wings during this soaring flight. I also have footage of an R/C wing flying out at Torrey Pines earlier in March.

So dust off that model, pack it in the car and bring it to the meeting.



LETTERS TO THE EDITOR

April 7, 2003

TWITT:

I am trying to find a picture of what is supposedly the last U-2 wing Don Mitchell built. It won the Western Design Homebuilt contest. It was called the Stealth 11. I'm told there is a picture of it in your archives. Any ideas?

Vince Tracey
ixlan2@mcleodusa.net
www.sadlervampire.com

(ed. – I updated the Mitchell page on our website and sent Vince the link so he could see what we have for pictures. I have not heard back from him so am not sure if we provided what he is asking for. If anyone has pictures they would like to include, please forward them to me and I will forward them. It will also allow us to increase our archives with additional Mitchell pictures.)

April 8, 2003

TWITT:

I have a German airplane compass, mother compass (mutterkompaB) that I would like to sell. Do you know of anyone who may have an interest?

Thank you.

clayb@cox.net

(ed. – I have also included this item on the website so it may be gone by the time you read this newsletter, but if you are interested drop him a line.)

April 22, 2003

TWITT:

I am interested in building an example of the Fauvel AV 60. George Jacquemin gave me some very rare16 m.m. color film of the AV 60 on its taxi trials and test flight. The aeroplane has a brisk take-off and flies very well. Could you help me with this please?

Thanks,

Rob
rjg@paradise.net.nz

(ed. – We don't have very much on the Fauvel designs except for some pictures and drawings. If anyone has plans or knows where they can be obtained for the AV 60, please let Rob and TWITT know. Thanks for your help.)

April 23, 2003

Fellow R/C modelers:

If the sad news has not reached you yet, it has happened again, our flying community has lost another expert and prolific contributor. You may want to update your web site links or other on-line references accordingly.

Jack Lynn Bale of 'Jack Bale Plans' (http://web.dreamsoft.com/jackbale/homepage.htm) passed away suddenly in late March 2003 after apparent recovery from a previous illness. Jack authored plans and produced parts for approximately 70 exact scale flying replica aircraft.

Some may have credibly regarded Jack as an eccentric hippy. In fact, he was a CREI educated electronic technician and mechanical draftsman, multiple contributor to Scale R/C Magazine and other r/c publications, electric scale propulsion pioneer, international exporter of model products, Planes of Fame Museum contributor and hang glider pilot.

Among Jacks last plans were a Consolidated Vultee XA-41 and a F84E (straight wing) Thunderjet, which was my first successful effort to move Jack closer to seeing computer drafting as worthwhile (old GOOD habits do die hard). I was also collaborating with Jack on a CAD 1/6 scale Navion.

Jacks vellums and vacu-form plugs have been donated to his local club. Should any established vendor be interested in continuing Jacks business, there may still be time. That club is La Sierra Slope Soarers of Riverside, Calif and their presidents email address can be had from their web site; www.lsss.homestead.com.

Glenn Paul Jones
j1s@dslextreme.com

(ed. – I included this for our modeling members just in case they haven't heard the news yet. He had some flying wing model plans and parts, but they may no longer be available unless someone steps up to take over his business. We will keep you informed, if we learn more about this option.)

(ed. – Here are some bits and pieces from recent Nurflugel Mailing List discussions.)

April 6, 2003
From: jbergmeyer@t-online.de
Subject: paper flying wing

Hi all,

Do you know this paper flying wing? It flies great - your living room will be too small!

http://www.paperang.com/Paperangshare.pdf

Regards, Jochen

April 11, 2003
From: "Northrop N9M" <northropn9m@yahoo.com>
Subject: Flying Wing and Adverse Yaw Questions

As many of you know, I built an 8' flying wing based upon Northrop's N9M. I used an Eppler 334 airfoil and a single pusher prop powered by an OS .46FX engine. There is 4 degrees of linear twist in the wing. Pictures can be found here: http://photos.yahoo.com/northropn9m.

I have been flying the wing and have not experienced the adverse yaw I was expecting. The plane seems to make turns with only a bit of adverse yaw and I seem to be the only one that notices it. Other pilots on the ground do not see it. Occasionally, the plane will oscillate in the yaw axis but only for two cycles, which last less than two seconds.

I'm scratching my head wondering why I am not experiencing more adverse yaw. Did I set my yaw stability expectations too low? Was I expecting the worst? Does the airfoil (Eppler 334) have anything to do with the better-than-expected results? Is the 10" prop spinning at 11K RPM acting as a gyroscope and providing some yaw stabilty?

Thanks for your feedback. Much appreciated.

Jeff

From Norman Masters <nmasters@acsol.net>

The person with the controls has a psychological advantage, you know the precise instant and way that the stick was moved, the observers only see what they see when they see it.

Yep, flying wings with linear washout and no verticals are directionally unstable (but only two oscillations isn't bad at all). That's one of the reasons the XB-35/YB-49 didn't get the USAAF contract, in the old days bombers had to be rock steady in order to hit a target with dumb bombs (and even then they had to drop hundreds to be sure of hitting a specific building).

"I'm scratching my head…" Yes

"Was I expecting the worst?" Yes

"Does the airfoil (Eppler 334)…" Probably not.

"Is the 10" prop spinning…" The pusher prop dose have a positive effect on stability but it's not very big. It's also not gyroscopic, the propeller acts like a fin, as long as the airflow is parallel to the prop shaft there isn't any side force but when the air enters the prop disk at an angle there's a force trying to bring the shaft back into the wind. You could prove this happens, and is not due to gyroscopic force, by putting an engine test stand on a turntable and using a fan to simulate yaw, the test rig will turn (slowly), either into the wind or away from it, depending on what side of the turntable axis the prop is on. It's just like putting a fin on an airplane, in front of the CG is slightly destabilizing and in back is stabilizing, with the difference that the prop's effect is in yaw and pitch.

Look at your hinges; if the top looks different than the bottom (as it would with a skin hinge) it's possible that the up going aileron has more drag than the down going one. If that's the case the increased profile drag would partially compensate for the increased induced drag of the other wing.

From Art Kresse <akresse@comcast.net>

I noticed from the close up photo of the aileron that the hinging is on the top surface and as near as I can tell the geometry of the linkage gives more up than down throw. I have designed and built two successful wings of approximately the same geometry as yours. In both cases I found I needed about 3 to 1 differential aileron (more up than down) to get a well-behaved turn. Some of the details are found in an article by me on the Nurflugel web site. If you would like more details let me know.

Back from Jeff: Art, You know, that is something that I forgot to mention in my email to the group. I did install differential aileron, however, I do that to my standard RC planes and did it automatically not thinking that this might help the adverse yaw situation. You are right, the elevons are hinged on top and I do have more up then down. I read your article on the Nurflugel web page. Thanks so much for your help and feedback. Much appreciated.

More from Jeff: First of all, thanks so much for the feedback on my adverse yaw questions. I am humbled by the expertise and experience in this group.

My wing is flying well. I think it is still nose heavy (although I have the plane balanced at 10.5" -- see calculations below) or maybe the 4 degrees of downthrust from the pusher engine may be holding the nose down too much. The reason I say it might still be nose heavy is the elevons must be deflected +10 degrees from where they are flush with the top of the wing surface to achieve level flight. I am wondering, is this too much? +10 degrees? Or is this normal?

I do not seem to be running out of elevator upon landing and the plane rotates smoothly with up elevator during the take-off roll.

The aerodynamic stats on my plane are as follows:

Sweep Distance @ MAC (C) = 7.99"
Mean Aerodynamic Chord (MAC) = 13.46"
MAC Distance from Root (d) = 17.57"
Balance Point @ Root Chord (CG) = 10.54" @ 19% MAC

My only experience with flying wings is with a Zagi and I know that the elevons are set with positive deflection.

I read Dr. Nickel's paper at http://www.nurflugel.com/Nurflugel/Papers/Dr_Nickel_Paper/body_dr_nick el_paper.html and even flight-test data from Mr. Northrop's N9M and I understand that "up elevon" is part of stabilizing a wing.

I am just wondering, how much "up elevon" is too much.

I appreciate your feedback. Thanks so much!

Jeff

AERO ELASTICS OF LIGHT TAILLESS AIRCRAFT

By I. H. Culver

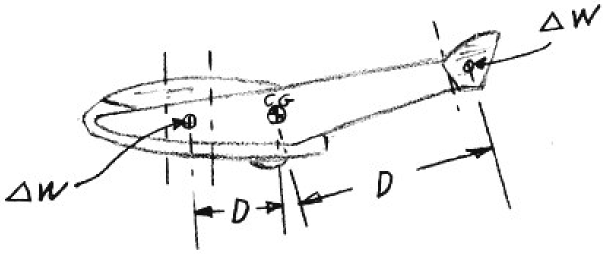
November 22, 1986

Flutter analysis of conventional aircraft generally neglects the pitching motion of the aircraft as a complete airframe. This is okay since the moment of inertia in pitch is high and the possible flutter frequencies are high. Result is that body-pitching amplitudes are near "0" for conventional aircraft. Therefore an analysis of wing flutter can be made, assuming no body pitch motion, without appreciable error.

For tailless designs the assumption of no body pitch motion is okay for anti-symmetric modes since there are no net pitching forces on the complete machine. So for tailless designs the elevons could be mass balanced at the tip of the elevon for about 50 to 60% of the static unbalance, for anti-symmetric mode only. (Ref: "Physics of Flutter" by Culver) However, for the symmetric modes the aircraft pitching becomes a principle issue.

For tailless aircraft there are two modes of aero elastic instability possible that are not common problems with tail-last designs. The first and simplest is a flutter mode at the most forward CG allowed. This mode is symmetric wing flapping and pitching of the complete aircraft. This, if the CG of the aircraft is far enough ahead of the AC (aerodynamic center) and the pitching moment of inertia I_p is low enough, so that the aero lift as you increase speed stiffens the aircraft pitch to the point where the pitch frequency is equal to the flapping frequency, result: flutter.

It is relatively easy to measure flapping frequency on the ground. It is possible to estimate moment of inertia in pitch I_p. With a side view of the aircraft, cut the weight (W) into small pieces. The distance from the CG to any piece of weight is (D).



$$\frac{\Delta W}{G} \times D^2 = \Delta I_p$$

If you sum up all the little weights in lbs divided by the acceleration of gravity (G) X the square of the distance from the CG in the side view in fee (D^2) you get:

$$\sum \frac{\Delta W}{G} \times D^2 = I_p$$

I recommend using slug ft^2 for I_p to keep the numbers from getting too big.

G is 32.2 and W is in lbs.
D in feet
So I_p is in slug ft^2

Now, if the aerodynamic angular stiffness in pitch is the slope of the lift curve them the dynamic pressure $q = \frac{1}{2}\rho V^2$ times the wing area S_w and times the distance from the CG to the AC then we can write the pitch frequency.

$$\left[\frac{(CG\ to\ ac) \times C_{L\alpha} \times q \times S_w}{I_p}\right]^{\frac{1}{2}} = \text{PITCH FREQUENCY RADIANS PER SEC.}$$

(CG to AC) is at the most forward CG expected. (CG to AC) must be in feet since all other dimensions are in feet and lbs. So divide (CG to AC) in inches by 12. Now to find the frequency in cycles per sec we divide by 2π

$$\frac{\left[\dfrac{\overset{\text{INCHES}}{\overset{\downarrow}{(CG\text{ to }AC)}} \times C_{L\alpha} \times q \times S_w}{12 \qquad I_P}\right]^{\frac{1}{2}}}{2\pi} = \underset{\overset{\uparrow}{CPS}}{\Omega_P}$$

To find the flapping frequency on the ground, shake a wing tip with someone in the cockpit and supported on soft supports, like a soft tire plus an old tire front and rear to prevent tipping in pitch. Vary the shaking frequency until you find the first symmetrical mode. Shake at this frequency while counting the cycles for 10 seconds; then divide the count by 10 to get cycles per second. Most people can shake and count up to and some above 3 cycles per second. If the frequency is above 3 cps then you don't have a problem for this class of homebuilt aircraft. This frequency we will name Ω_F F for flap and P for pitch. Now if Ω_P comes close to Ω_F you have pitch flap flutter. $\Omega_P = \Omega_F =$ Flutter

$$q = \tfrac{1}{2}\rho V^2 \quad \text{OR} \quad q = \frac{(MPH)^2}{391}$$

V = DESIGN DIVE SPEED

$$C_{L\alpha} = \frac{2\pi}{1+\frac{2}{AR}}$$

AR = WING ASPECT RATIO

Now for the second possible mode of aero elastic instability, this one sets the aft most CG for a given design dive speed. This form of aero elastic phenomenon is called pitch divergence. However, when a pilot is part of the act the non-oscillatory pitch divergence of the airplane becomes oscillatory. So to the pilot and the observers the problem appears to be flutter.

This problem is not simple. We will not attempt to couple the pilot's response into the problem, since this is supposed to be as simple as possible to apply. For small light aircraft the difference in speed where the phenomenon occurs is small due to pilot response.

The following is an attempt to simplify the problem to the lowest level possible and still help in the design of tailless light aircraft. Pitch divergence in a tailless machine is caused by the geometric effects of the sweep and the flap wise deflection of the wing causing a pitching moment. In its simplest conceptual form the Δ twist in a sweptback wing due to wing bending is proportional to the number of G's you pull. Next, at a given angle of attack the number of G's is proportional to V^2 so the (Δtwist)/(Angle of Attack) goes up as V^2. The Δ wing twist acts like control input. The faster you go the more effect the wing Δ twist has. An approximate equation for the AC shift due to aero elastics is:

$$\begin{array}{l}\text{INCHES}\\ \text{OF}\\ AC\\ \text{SHIFT}\\ \text{FORWARD}\\ \text{TO } AC_\varepsilon\end{array} = \frac{\left(\frac{W_A - W_W}{W_A}\right) \times b^3 \times \left(\frac{2\pi}{1+\frac{2}{AR}}\right) \times q \times S_W \times (TAN\,A)^2}{E \times I_S} \times .0004$$

(EQUATION 3)

When the (AC_ε) shifts forward to the CG the result is PIO.

NOMENCLATURE

W_A = weight of airplane lbs.

W_W = weight of wing lbs.

b = wing span inches tip to tip

AR = aspect ratio of wing

$q = \frac{V^2}{391}$ where V is in MPH design dive speed

S_W = area of wing in sq. ft.

A = sweep angle of elastic axis

E = modulus of elasticity of the spar

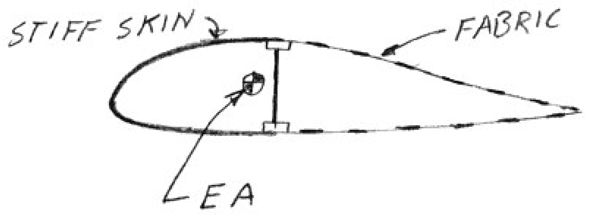
I_S = moment of inertia of the spar at the half semi-span point $(\text{inches})^4$

aC_ε = aerodynamic center including aeroelastics

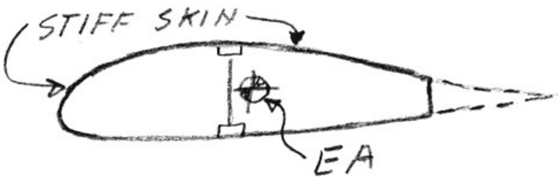
The above equation assumes that if area is added to the spar caps to increase I_s at the mid semi span point, this added area is not just a local lump, but is tapered out to root and tip in a smooth curve.

This equation says that the CG must be ahead of the AC of the wing by the amount given by the equation or pitch instability will result at a lower speed than anticipated.

There are several problems left. Where is the elastic axis? For "D" spar wing the elastic axis or shear center is a little ahead of the spar.



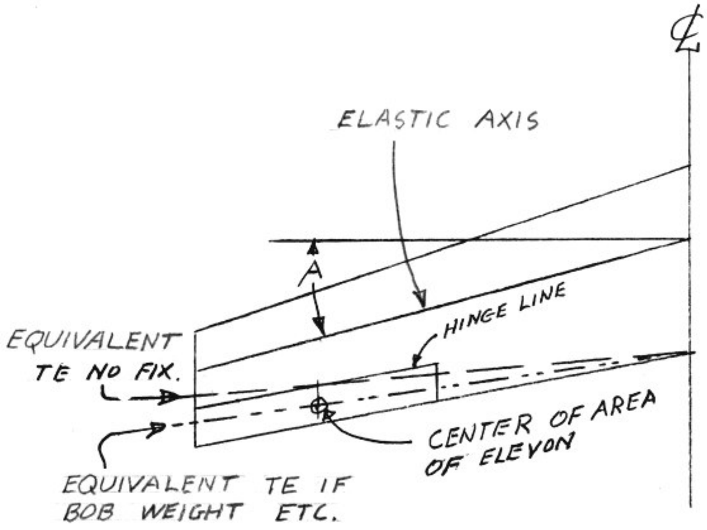
For a fully stiff skinned wing the shear center (elastic axis) = EA is aft of the spar.



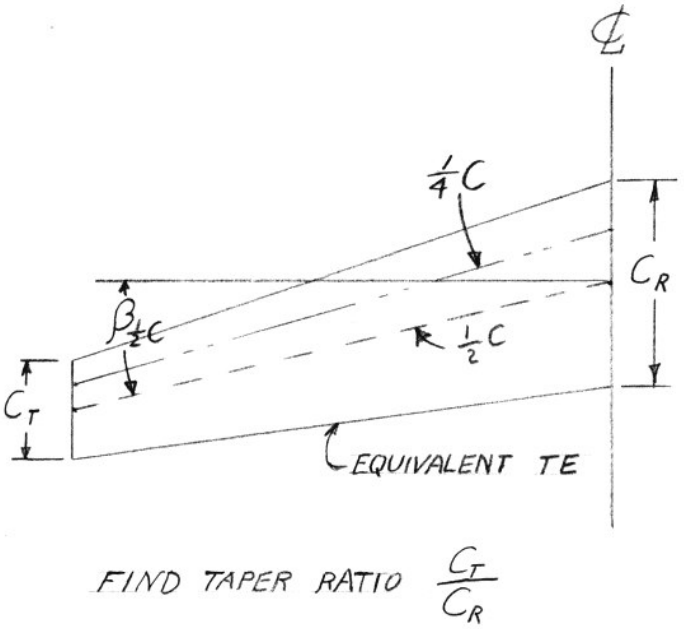
Where is the AC of the wing? The first problem is the effectiveness of the elevons. Unfortunately elevons tend to float up with increasing angle of attack, making them ineffective as part of the aero elastic wing. Freeze aileron type aerodynamic balancing is not appropriate due to the nonlinear hinge moments when used as elevators. So the only thing left to make the elevons act at least to some extent as part of the wing is the use of a bob weight in the center of the aircraft.

Balance the elevons at the tip only for first mode anti-symmetric flutter. This makes the elevons trailing edge heavy for the static pitch divergence mode, so that positive maneuvering tends to put the trailing edge down, counteracting the nose-up tendency due to the above. Also the bob weight on the stick will help. (Up acceleration results in nose-down stick.) Further, design the control runs in the wing out to the elevons so that up bending causes the trailing edge of the elevons to go down.

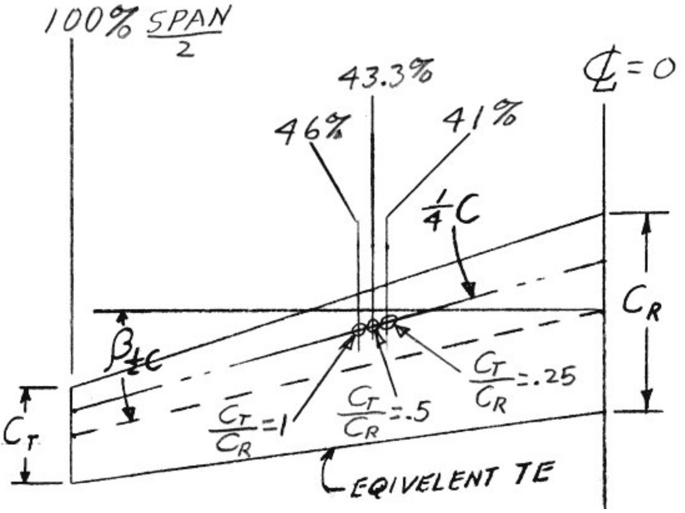
An explanation of the above is: if you bend the wing up the top surface of the wing shortens and the bottom lengthens, so if you run wires out the wing to the elevons with the upper wire as close the top of the wing as practical and the bottom wire close to the bottom, with the top wire going to the top horn on the elevon and bottom to bottom horn, then if you bend the wing up the trailing edge of the elevon will com down. Location of the bob weight fore and aft is important since it could cause another form of flutter. The ideal for and aft position of a pitch bob weight on the centerline can be determined by shaking the aircraft (fully loaded) by hand from one wing tip at fist mode symmetrical flapping frequency while supported on soft tires so that the center body is free to pitch and plunge. Next find the fore and aft point on the centerline where the vertical motion is minimum. This is the best spot (fore and aft) for the bob weight. The bob weight is connected to the stick in such a manner that down motion of the bob weight caused the stick to move forward. The aft force on the stick to support the bob weight at 1G flight should not exceed about 2 lbs., otherwise excessive stick shaking will be annoying in rough air. The nose down trim effect of the bob weight is trimmed out with tabs on the trailing edge of the elevons. The result is improved speed stability and improved Phugoid stability, as well as making the elevons act as part of the wing.



Back to the problem of finding the aerodynamic center AC of a rigid tailless wing, corrected for the floating effects of the elevons.



Next, find the spanwise point on the ¼ chord line of the equivalent wing that represents the effects of taper ratio using (Schrenk).



D_S is the distance from the no sweep AC to the AC with sweep.

EQUATION "4"

$$D_s = \left(\sin \beta_{\frac{1}{2}c}\right) \times \left(1 - \frac{1}{AR+1}\right) \times \frac{b}{\cos \beta_{\frac{1}{2}c}} \times .02$$

b is total span in inches so D_S is in inches.

The rigid AC with sweep is the non-elastic aft CG limits, so starting from there the aero elastic loss (Equation 1) moves the allowable aft CG forward.

12/24/86

Dear Irv:

I still need to study your tailless aero elastics further, but will send a few comments. Been working full time again at Rockwell up to the holidays.

Page 3, bottom equation – I believe the square root sign was left off. Pages 6-7 – A little sketch to show where the equation comes from might help the curious reader.

The fact that the trailing edge of a cut parallel to the CL lies further out on the structural axis than the leading edge and when in combination with cantilever beam bending give a wash out shifting load inboard and AC forward.

Bruce (Carmichael)

APPENDIX

Equation 3 is a gross simplification of the static aero elastic effects on the aerodynamic center. The first term on the top of the equation W_A = weight of airplane. W_W = weight of wing. So $W_A - W_W$ = the load on the wing not directly supported by the air load. Any load directly supported by air load does not cause bending moments on the wing. So $W_A - W_W$ is the load that causes bending. If we divide this by WA we have the percentage of the air load that causes bending. Result $(W_A - W_W)/W_A$.

The next term b = span of the wing and the lower terms E x I_s are involved in the elastic deformation in bending.

$$\frac{M}{EI} = \frac{d\alpha}{db} \text{ or } \left(\frac{Fb}{\cos A\, EI}\right) \approx \frac{d\alpha}{db} \text{ and } \left(\frac{Fb^2}{(\cos A)^2 EI}\right) \approx \alpha$$

Where α is a deflection angle along the elastic axis. If we wish to find a pitching moment from this we would have to find the fore and aft moment arm, this ≈ b tanA so now we have

$$\frac{Fb^3 \tan A}{(\cos A)^2 EI} \approx \alpha$$

Now α is along the elastic axis, not stream wise so must multiply by the tanA and multiply by the cosA or (tanA x cosA). Summing this up to this point we have

$$\frac{Fb^3 \tan A \;\; \tan A \cos A}{(\cos A)^2 \;\; EI_s} \times \left(\frac{W_A - W_W}{W_A}\right)$$

$$\text{or} \quad \frac{Fb^3 (\tan A)^2 \left(\frac{W_A - W_W}{W_A}\right)}{\cos A \times E \times I_s} \approx \text{ac shift}$$

Now if we substitute the lift force $C_{L\alpha}\, q\, S_w$ for F

using $C_{L\alpha} = \left(\frac{2\pi}{1 + \frac{2}{AR}}\right)$ and rearrange we have

$$\frac{\left(\frac{W_A - W_W}{W_A}\right) \times b^3 \times \left(\frac{2\pi}{1+\frac{2}{AR}}\right) \times q \times S_w \times (\tan A)^2}{\cos A \times EI_s} \approx \text{the ac shift}$$

Now the only problem is to get rid of the wiggly lines ≈ and make the equation reflect real dimensions and approximate answers. The .0004 was found to give answers within ± 15% for 3 types of widely different designs.

Some after thoughts you could multiply the slope of the lift curve by cosA to approximately account for the reduced slope of the lift curve due to sweep. This would eliminate the cosA on the lower side of the equation and make the approximation a little more accrete for large sweep angles as well as simplifying the equation.

Equation 4 is an extraction from a previous paper ("Tailless Flying Wings" – ed. - See March 2003 issue of TWITT Newsletter) and modified to represent the aft shift of the AC due to the effects of sweep.

A note on tip fins or tip rudders. It should be obvious that if the tip fins together weighed the same as the center body the aero elastic effect would be reversed. This positive maneuvering would cause a nose down aero elastic effect. So a simple correction for the weight of the fins at the tips is to add 8 times the tip fin weight to the wing weight. Use

$$\frac{W_A - (W_W + 8W_T)}{W_A} \text{ instead of } \frac{W_A - W_W}{W_A}$$

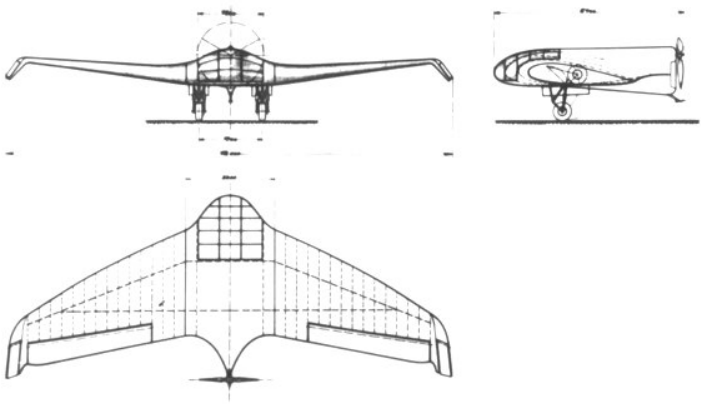
Where W_T is the weight of both tip fins. Note that adding weight to the tips improves the pitch divergence case (aft CG), but makes the forward CG flutter case worse because it lowers the first symmetrical flapping mode frequency.

Note – This paper does not include wing torsion.

LIPPISCH DFS 40 (Delta V)

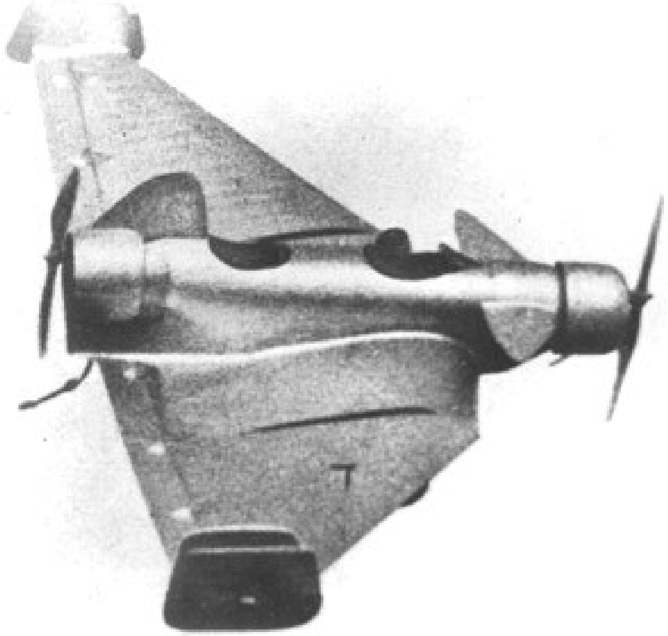
1935

(These pictures came from the collection of John W. Caler and came into the TWITT archives.)

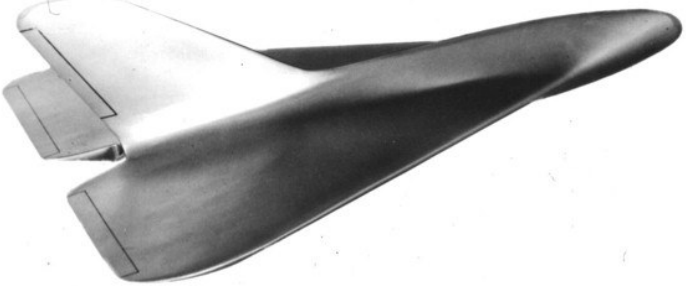


From the memo included by John Caler: "The DFS 40 Delta V crashed during the summer of 1939 after Rudy Opitz lost control of the aircraft in an unintentional spin. Since Lippisch went to Augsburg and the Messerschmitt A.G., the team at DFS that took over the project exhibited their lack of experience in shifting the center of gravity well beyond the limits of safe flight. Opitz bailed out at very low altitude and his parachute had not fully opened when it caught in the top of the trees where the aircraft crashed. He escaped without injuries and suffered only minor scratches on the long way down the tall and branchless tree trunk."

ABOVE: "Gunther Gronhoff at the controls of the Storch V in 1929, just after he took over Lippisch's flight test program."



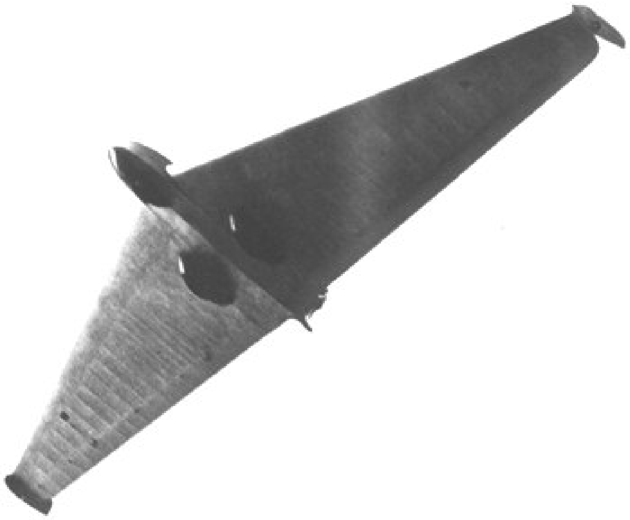
ABOVE: (Text from Unconventional Aircraft by Peter M. Bowers, 1984, p. 50) "An example is the Fieseler W-3 *Wespe* (Wasp), a unique twin-engine tailless that Lippisch called Delta IV. In addition to the novelty of two 75-hp British Pobjoy engines, one pushing and one pulling, the Wespe had folding wings. It was also one of the first aircraft – if not the first – to use a fixed canard surface to redirect airflow over the wing root. This feature has become very popular on the high-performance deltas of the 1980s."



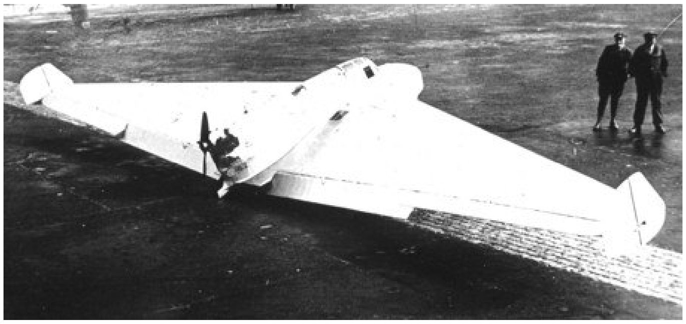
ABOVE: Lippisch's final tests at Vienna saw the introduction of the P 15, which was to have been powered by a turbojet.

ABOVE: Gronhoff sweeps low over Tempelhof Airport (Berlin), with the Delta I on October 25, 1931, while on a test flight of the aircraft for Lippisch. Unfortunately, airport officials who gathered to watch were alarmed and demanded that a tailplane be added before a certificate of airworthiness could be issued. (From Unconventional Aircraft "The notable design detail of the Delta I was that while the leading edge of the wing was still swept back at a comparatively shallow angle, the sweep of the trailing edge was eliminated by having it run a straight line from tip to tip. This is historically significant in that it started the development of the *delta* wing, which was not to become successful until after World War II – and then proved to be pioneered by Lippisch.

"Because his new wing was more like a broad based triangle than an inverted letter V, Lippisch named it Delta after the Greek capital letter, even though the proportions were way off. Delta I was not put into production, but led to later Deltas.")



ABOVE & BELOW: The very successful Delta I during flight-testing in mid-1931. Gronhoff found the aircraft to be more than satisfactory during the initial flight tests. A low pass in front of the cameras: the Delta I had its fixed landing gear faired into the wings. The 30-hp Bristol Cherub engine gave the well-designed aircraft a good margin of performance, a testimony to the farsighted aerodynamic concepts Lippisch was attempting to visibly demonstrate.



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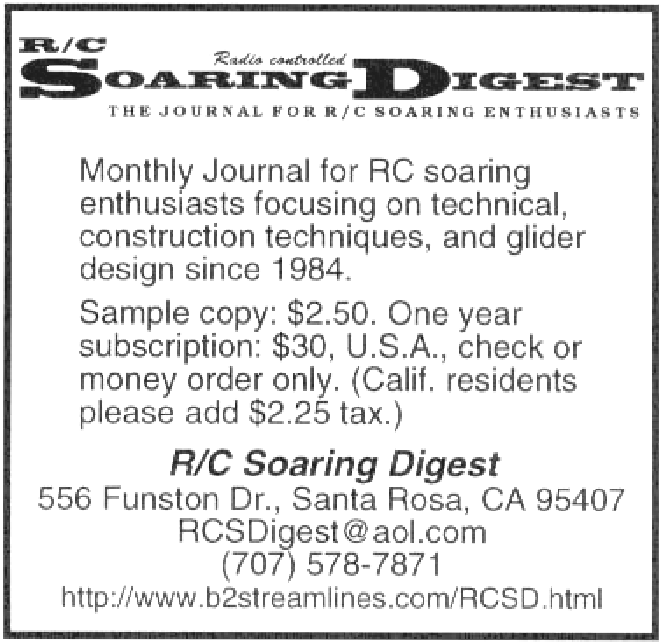

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