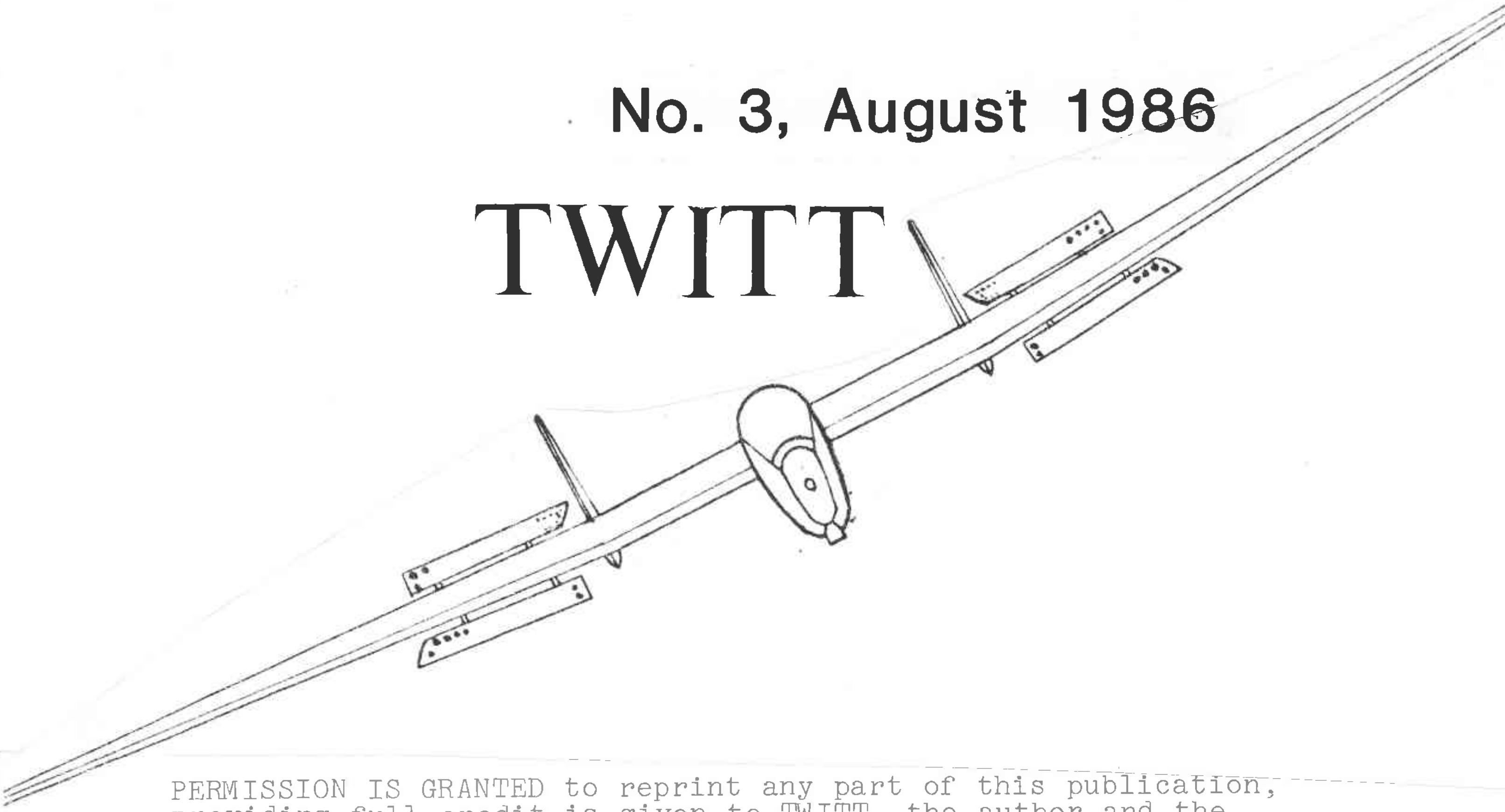
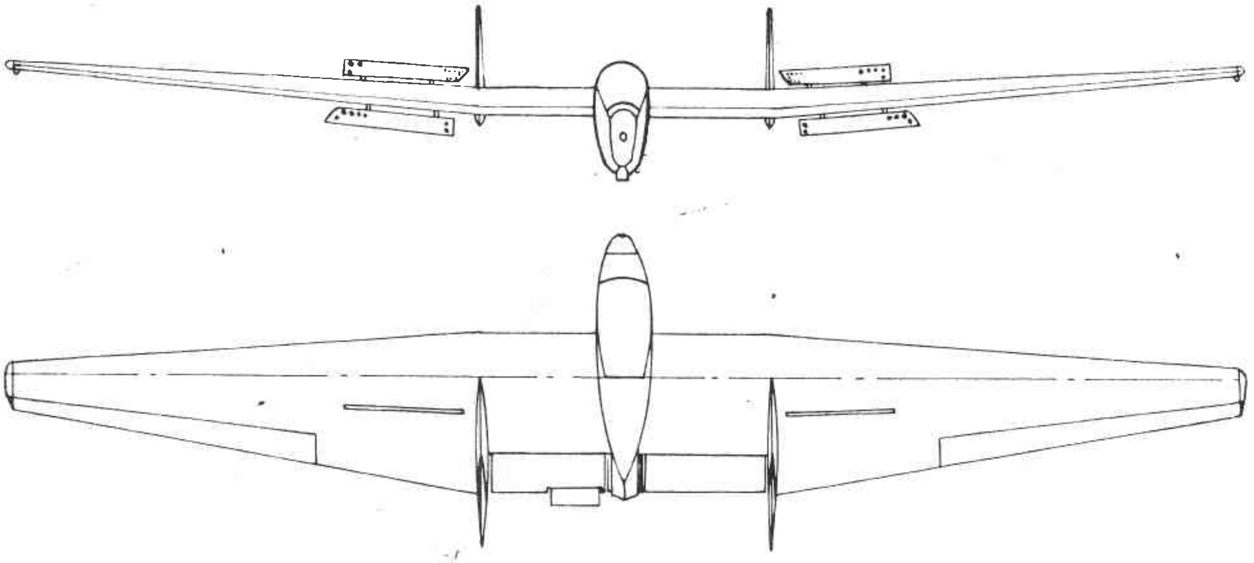
No. 3, August 1986

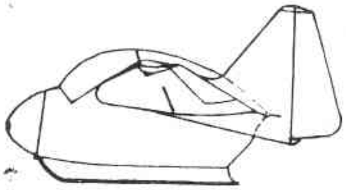
TWITT



TWITT
(The Wing Is The Thing)
PO Box 20430
El Cajon, CA 92021

Telephone: (619) 224-1497 before 10 AM or after 10 PM

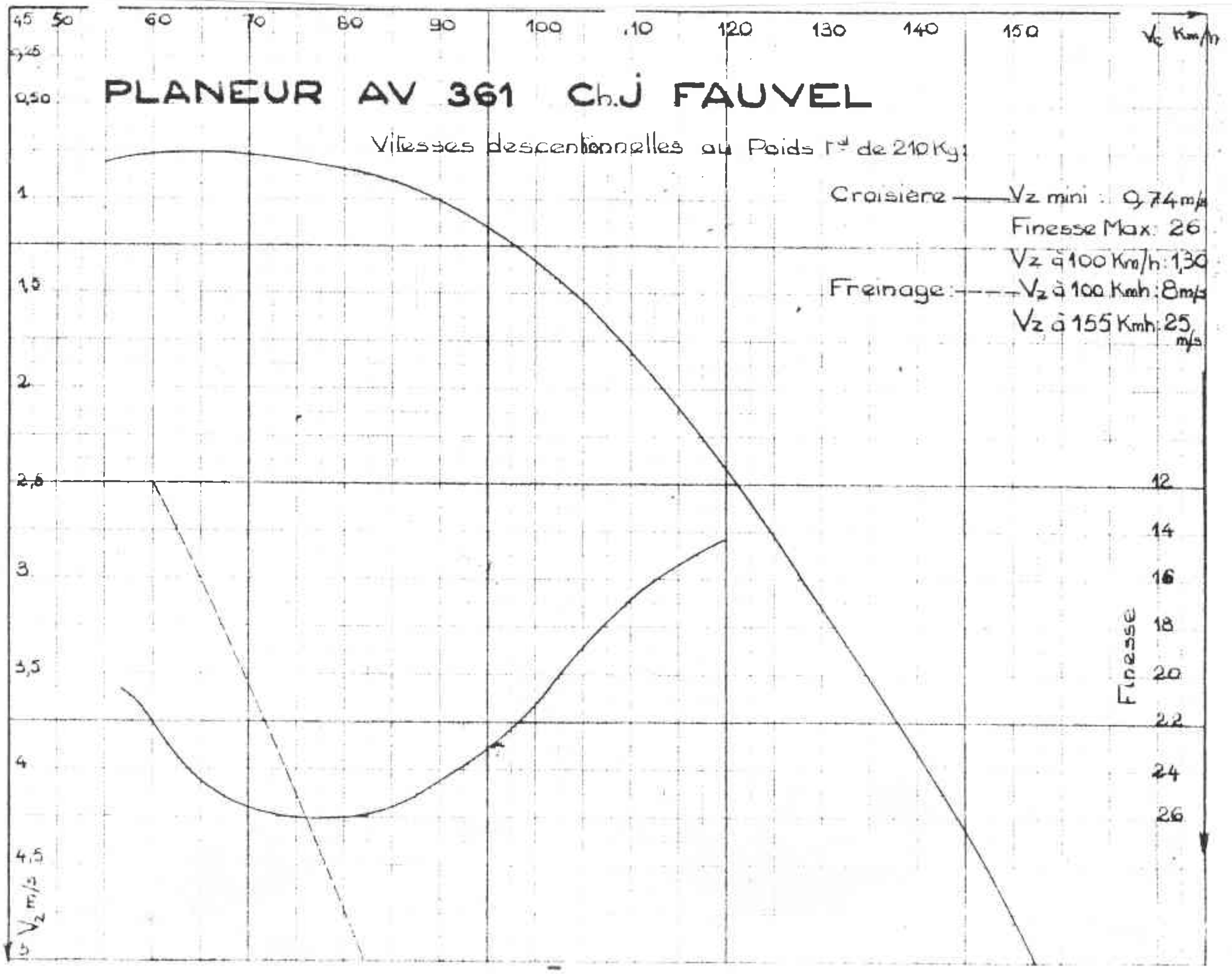




Envergure: 12,78m.
Longueur: 3,24m
Surface: 14,60m²
λ: 11,4
Poids Vide Eq: 125 Kg
Nb Gouvernails rabattus ou démontés et Casserole enlevée, la longueur tombe à 2m 46, permettant le transport en travers sur route.

Finesse Max: 26 à 82 Km
Pilote de 75 Kg {Descente Mini 0,74 m/s
Pilote de 75 Kg {Descente à 100Kmh: 1,30m/
P_t (Facteur 12 à Rupture): 215 K
P_t (d° 10 d°): 258 K

PLANEUR Ch et J. FAUVEL d'Entrainement, Performances et Nuages
Type AV. 361 "Monobloc" (AV 36 Mk II)



MINUTES OF THE THIRD TWITT MEETING, 23 AUGUST 1986

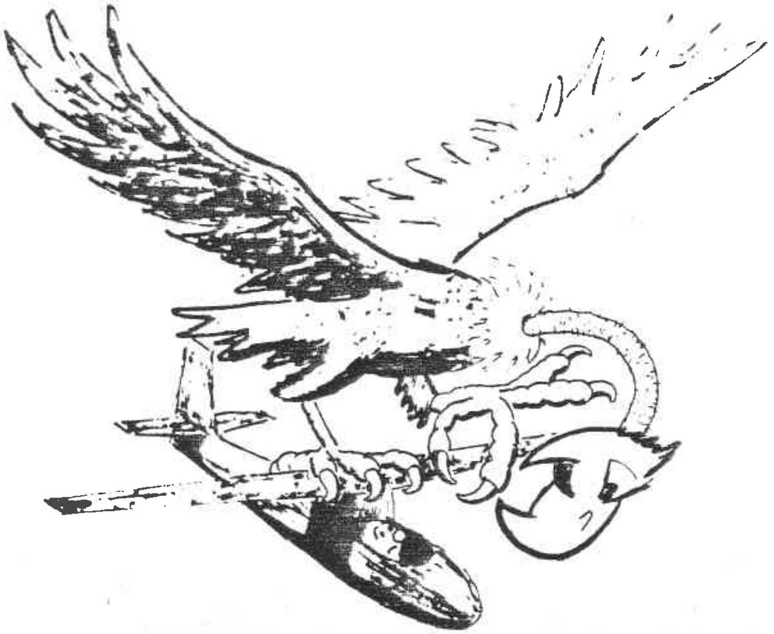
The third TWITT meeting took place at the Fronius lair on Skid Row on 23 August. Present were the usual TWITTs, minus Richard Miller but including Hernan Poznansky who managed to make it this time, plus Vern Oldershaw, Jerry Blumenthal, Andy Custis (phonetic spelling) and Pablo de Petris, an Argentine friend of Phillip Burgers. Jerry is retired from GD/ Convair, where he built models for wind tunnel testing. He is thus a model builder by trade and a dreamer by avocation. He brought with him to the meeting several sketches of bizarre-looking but well-conceived machines, several of which were tailless. He also volunteered to use his model-building skills for the group's benefit! Vern Oldershaw is a designer and builder of considerable experience and repute. He is perhaps best known for his collaboration with Paul McCready on the Gossamer series of man-powered airplanes. But he is also a closet Wing buff and has given the matter considerable thought. Vern opened the meeting by presenting a powered radio controlled 1/4 scale model of a motorglider which he hopes to complete someday, cash and time permitting. Specs are: AR 14.25, 3 degree sweep forward on outer panels, unswept center-section, 2 1/2 degree wash-in at the tips, c.g. at 18% mean chord, 3 degrees dihedral. Wing chord is increased inboard of the twin vertical fins to allow deep-chord elevators. The ailerons, elevators and rudders are interconnected as follows:
--elevators depress whenever aileron input is given
--rudders deflect with ailerons
--the linkage incorporates a good dose of aileron differential.
Vern also discussed the Davis (David R.) patented airfoil section formula. He noted that by choosing different values for the various constants in the formula one can generate highly cambered, laminar flow or even reflex-cambered airfoils. Vern has his computer programmed to provide sixty-point plots of sections generated from the Davis formula. The model's section was produced in this fashion, with the parameters chosen to give a reflexed mean line intersecting the chord line at about 80% chord. Vern's program does not generate the mean line directly; it must be plotted by hand. Vern noted that his model maintains a turn "hands off" and that it is less pitch-sensitive than earlier, less washed-in models. He has built 18 to 20 other tailless models, many of which were lost to instability in tow. Jerry Blumenthal discussed airplane layouts and expressed the opinion that the canard layout is the most efficient because the control surface carries an up load. Vern mentioned that he thought his washed in wingtips might be acting as a sort of virtual canard, preventing the wing as a whole from stalling; he suspects that the Minibat accident may have been caused by insufficient wash-in. He mentioned that he had tried winglets on one model, which however was so directionally stable that it almost refused to turn. Vern added that a sailplane with washed-in tips will automatically turn into a thermal because an increase in lift on the inner tip brings a consequent increase in drag, yawing the machine into the up-

draft. A ten-minute break ensued.

Following the break, Hernan assumed the Chair and brought up the subject of stability. He and Bruce Carmichael noted again the intimate connection between pitch stability and lift distribution in both forward- and aft-swept wings. Bruce asked Marc de Piolenc what methods were available to a small group like this one for analyzing a wing's lift distribution. Marc replied that from his reading it appeared that analyzing an existing wing was more complicated mathematically than designing a wing for a chosen lift distribution. A simple graphical technique for the latter purpose had been developed by Doris Cohen at NACA in the forties. Bruce mentioned a NACA Report in the 800's by R.T. Jones in which Jones presented a wing which showed an elliptical distribution of lift at the design lift coefficient, and a bell shaped one below that. Your editor vowed to find it [and subsequently did]. The subject of yaw stability was brought up and the question of whether one should seek to make it inherent in the wing design (Horten) or add it with vertical surfaces was batted about without any conclusion being reached. The meeting was then closed.

Airing grievance

"I think it's ludicrous," said M. Robert Blanchard, chairman of the Airport Commission, about Winooski, Vt.'s, tax bill to the Burlington International Airport. Glide paths and approach ways are "measurable surfaces that can be viewed as necessary extensions of the airport itself, since, without such space, the airport would not be operable," said a memo compiled by Winooski officials, arguing that planes approaching and leaving the airport take up the city's airspace. The airspace was assessed at $3,563,300, resulting in a tax bill of $90,222, said City Manager Brendan Keleher.



THE STABILITY AND CONTROLLABILITY OF ALL-WING AIRCRAFT

Fifty years ago, with the decision to realize the flying wing patented by Junkers (German Patent 253,788 of 1 February 1910), the theme that dominated research carried out between 1925 and 1931 at the Forschungsanstalt Prof. Junkers (Prof. Junkers Research Center) made its apppearance. The flow mechanics division was to determine what flight possibilities existed in the unstable region, that is with the c.g. behind the neutral point, as Doepp reported in Lilienthal Advance Report 164 in 1943. This research now seems quite modern, since the control of fast airplanes requires low, nearly neutral static stability in order to keep actuation forces to a minimum; in slow airplanes too this neutral stability is desirable in order to suppress large-amplitude flight path oscillations, or phugoids.

With the flight tests of my first airplane in 1933 here appeared additional, surprising insights: while Doepp's research concerned itself primarily with stability and control about the lateral axis, I ascertained that it was the vertical axis that determined the flying qualities of the all-wing airplane. Hence, moments and controllability about all axes must be discussed here, the vertical axis foremost; the aft c.g. envelope, i.e. the permissible range of rearward c.g. travel and the lift range, or rather the angle-of-attack range, appear as parameters. Mach number and forward c.g. travel are excluded; these require special research.

Vertical Axis: Directional stability must be distinguished from weathercock stability. Directional stability means that the airplane mmaintains its heading when disturbed by a lateral gust, as is usually the case in model airplane flight, while weathercock stability refers to aerodynamic moments which arise in a crosswind or in yaw and turn the airplane. Negative weathercock stability is unflyable; the airplane immediately becomes unstable on all axes. Neutral weathercock stability is a requisite of directional stability and is desired for that reason. Increasing weathercock stability causes an oscillation of the airplane about the vertical axis in gusty weather. Since low or even neutral weathercock stability is sought and a clear dividing line must be drawn between this and negative stability, this specifies the aft limit of c.g. travel; and indeed it is with tail-heavy loading that a "swimming" motion, i.e. movement about the vertical axis, increases and becomes uncomfortable for the pilot. Now the all-wing airplane has the advantage, due to its spanwise loading, that c.g. movement is small; in sailplanes the pilot can even be placed on the c.g. so that different pilot weights produce no c.g. movement.

At this point moments about the vertical axis must be discussed. Unlike the conventional airplane, the flying wing experiences little or no moment from fuselage and empennage, at least to the extent that it is a true flying wing; but another consequence of this is that aerodynamic side forces are very small. The result for the pilot's point of view is that the ball in the yaw indicator, which is supposed to show apparent force by swinging outward when a side force is acting, is ineffective; the aerodynamic side force lacks the surface on which to act. A less tightly curved glass tube for the ball to move in would be helpful, but could not be manufactured due to standardization. In order to give the pilot a means of checking his piloting form it is possible to show him the stream direction directly by means of a woolen tuft glued to the front of the cockpit canopy. It turns out that this tuft indicates very effectively, jumping from left to right, provided that the canopy has a well-rounded shape. The first flights of the H.I revealed that the weathercock stability was slightly negative, for which reason the front of the canopy was shortened. Since plexiglas canopies were not commercially available in 1933, the part housing the pilot's head was angular, hence particularly unsuitable.

Another moment acting on a swept wing in yaw is caused by friction drag. If the wing boundary layer is turbulent, we can consider it to be acting at about 40% of the wing chord, that is behind the c.g. which is at 25% of chord. Friction drag therefore affects weathercock stability. If one uses airfoil sections with S-shaped mean lines having no center-of-pressure movement, such as the 8 or [9--?] NACA series, the flow on the underside of sailplane wings can remain laminar to nearly 100% of chord. In that case, the friction drag is considered to act at 20% of chord, that is forward of the c.g. At high angles of attack the pressure gradient is strong and with smooth construction the flow is laminar and the weathercock stability consequently lower. So it is that in slow flight the "swimmming" motion increases, decreasing again at maximum lift if flow separations having long moment arms in yaw occur on both sides. With a laminar/turbulent boundary layer, 50/50% for instance, the overall friction drag should be considered as acting at about 60% of chord, hence in a very stabilizing way. On the upper surface of the wing, where airfoil sections with S-shaped mean lines can have just such a transition point, we find on the rear half,that is on 25% of the wing's surface, about 75% of the friction drag; the remaining 25% of the drag apppears on the lower surface and the front half of the upper surface, that is to say on 75% of the wing surface. If the transition point, hence the friction drag, is different on the right and left panels due to yaw, unsymmetrical forces and moments arise. The determination of the boundary layer transition point is therefore relevant to stability about the vertical axis.

If the friction drag appears to be concentrated on the aft part of the upper wing surface, the location of the overall drag must also be placed there. On the high-performance sailplane Altostratus I (Soaring, Feb. 1981), the transition point is eliminated through suction provided by solar energy and laminar separation is taken into account, successfully it seems, since the sailplane's glide ratio--nearly 100--had never previously been achieved by any other airplane. Perhaps in the future the transverse pressure gradient in this zone could be employed to replace solar energy. Besides flight performance, stability in yaw would also be improved.

In connection with powered airplanes it must be noted that a propeller in front of the c.g. is destabilizing in yaw; hence the flying wing must have a pusher propeller, not only because of its stabilizing effect about the vertical (and the lateral) axis, but also because the propeller rpm and the side force interact to produce different moments in takeoff and landing, which is to say that stability is present.

The rudder must give the pilot the ability to produce moments which cause angular accelerations about the vertical axis for entering and leaving a turn, to compensate the aileron yawing moment and to compensate for unilateral engine failure on a multiengined airplane. It makes no difference whether the steering moment is produced by airbrakes on the wingtips or, as for instance in the case of short-span Delta wings, by fins with a vertical rudder. It should be noted that the drag rudder is effective at all angles of attack, whereas vertical stabilizers can be influenced by the wing center-section or fuselage and a Delta easily loses rudder effectiveness at high angles of attack.

How then do we use these three requirements to dimension the rudder effectiveness? For multiengined airplanes with asymmetric propeller rotation, requirements are established in detail by the design standards of the various countries. At a minimum takeoff speed, with extended landing gear and flaps in takeoff position, the direction of flight must be maintained even in a climb; permissible deviations are also specified. With these data, the lateral controls can be precisely dimensioned. For sailplanes, compensating the aileron yawing moment is usually the controlling consideration. Through use of a bell-shaped lift distribution the adverse yaw can be minimized, leaving only the desired angular acceleration for the rudder to produce. This acceleration is not prescribed and is left to the pilot's taste. The rudder on a flying wing can therefore be quite small, but in the interest of pure flying form cannot be left off entirely. There may also be special considerations such as spin entry or control in a crosswind landing which rudder effectiveness must satisfy.

Dynamic stability, too, about the vertical axis, which is supposed to appear as aperiodic motion, sometimes shows slow oscillations instead. The motion, which would otherwise take a long time to damp out, can be stopped by a brief deflection of the rudder. The motion can also be quickly stopped by deflecting drag rudders on both wingtips at the same time. The fact, observed again and again, that lateral stability is higher in a turn than in straight flight, still remains to be theoretically explained.

Longitudinal Axis: All movement about the longitudinal axis is strongly damped by the wing. Asymmetrical moments besides those due to gusts arise due to unilateral flow separation, that is at maximum lift, as well as through yaw at all angles of attack. The tendency to fall off on a wing at max. lift can be mitigated by the bell-shaped lift distribution; or it can be flown out of using aileron because the local lift coefficient at the wingtip is low and the aileron remains effective. A Handley Page-Lachmann slat at the wingtip is uncecessary with this lift distribution. It should be added that airfoil sections with an S-curve have a gradual rather than a catastrophic stall, leaving the pilot the necessary reaction time.

The problem is rolling moment due to yaw. Sweep and dihedral are clearly understood to be features of an all-wing airplane, dihedral being incorporated for the sake of ground clearance. At high angles of attack, sweep causes most of the rolling moment due to yaw; dihedral increases it at all lift coefficients, even in a dive at zero lift. A coupling therefore takes place with the vertical axis, becoming stronger at high angles of attack. This is a given fact for the flying wing which cannot be altered by design changes. If the wingtips are given a local negative dihedral, as in Wenk's Weltensegler and some Northrop airplanes, this measure can eliminate rolling due to yaw, but only at one C , not through the entire range, particularly not at high values. In landing or in a turn, always at high C , a wobbling motion called Dutch roll can occur. Because it is, as we have said earlier, linked to rotation about the vertical axis, it can be stopped by a brief rudder deflection or by the extension of drag rudders on both wingtips. If however static stability about the vertical axis is low, the necessary resonance does not occur. Recovery from roll angles caused by gusts requires that the ailerons cause only rotation about the longitudinal axis and (to avoid a harmful effect on the vertical axis) no negative yawing moment. The lift distribution should have a horizontal tangent at the wingtip so that a negative curvature prevails on the outer wing panel which produces an induced thrust at local positive lift coefficients, which in turn reverses the aileron yawing moment in this region, that is reduces or even nullifies the negative yawing moment.

Coupling of rotation of the airplane about the vertical axis with moments about the longitudinal axis is only noted in large-span sailplanes in circling flight. Even so it was possible to ensure trouble-free turning characteristics even in extreme cases, as for instance in the H III (10 kg/m wing loading and 20 meters wingspan), which not only refers to wing-dropping properties in a turn but is so defined that the airplane maintains its bank angle and turn rate with the ailerons and rudder both neutral, that is neither tightens its turn nor straightens out. This is important when flying blind inside cumulus clouds, since it reduces the load on the pilot while the sailplane flies itself; even the artificial horizon could be dispensed with.

Control about the longitudinal axis takes place with a combination of flaps so arranged that the sum of their deflections produces an elevator effect, while the difference in deflections between the right and left sides serves as the ailerons. The right and left flaps, each with up and down travel, require four stops, while the stick with fore and aft, left and right travel also requires four stops. The effect of having eight stops in all is to change the usual stick movement rectangle into an octagon. So it is that with the stick hard back only one-third of the aileron travel is available, while all of it is available when the stick is pulled back halfway. At full elevator deflection, too, the aileron travel is reduced, so that in aerobatics (roll), the aileron power should whenever possible be augmented by yaw.

The effectiveness of flaps on a swept wing is perhaps somewhat lower than on a straight wing, since the boundary layer flows toward them. This disadvantage can be reduced by increasing the percentage flap chord toward the wingtips. Frise type flap leading edges are especially helpful in this combined aileron-elevator arrangement.

Rotation about the longitudinal axis is aperiodic; oscillations have never occurred, due to the strong damping.

Transverse axis: Static stability about the transverse axis is always present in a swept and tapered wing, because the lift curve slope is high at the tips, that is to say the neutral point lies to the rear. Then, too, the wing center section forward of the center of lift, that is forward of the c.g., has a lower lift-curve slope because of the kink in the planform. If the c/4 line is rounded off by increasing the chord at the center-section, the reduction in lift is no longer noticeable, as in the H IV. In the H VI, the c/4 line was even swept forward [at the center-section] to determine whether the local lift-curve slope would then be higher than for an unswept wing, that is, whether the neutral point would move forward. Results of this kind are important to the layout of high speed airplanes in order to keep the static stability low and minimize control forces.

Because the local lift coefficient is kept low by the practice of increasing chord to round off the c/4 line, flow separation at the center section is not to be expected. In other words, the swept wing neither pitches down by the nose, nor falls off on a wing, nor pitches back over the two wingtips. The tips are protected from flow separation by the bell-shaped lift distribution; hence the wing remains controllable at and beyond maximum lift. Flow separation should occur near the trailing edge at 30-40% of semispan.

Near the ground, that is during takeoff and landing, all wings experience additional lift which depends on the ratio of the altitude to the wing chord. The center section of a swept tapered wing could then have 50-60% additional lift, while the tip might have only 10% because of its smaller chord. The lift distribution thus changes in near the ground in such a way that the center of pressure migrates in front of the c.g., creating a tail-heavy moment. As it happens, the airplane rotates easily for takeoff and flares automatically for landing and floats for a long time. One could hardly find any disadvantage in this.

In order to determine the stick free neutral point, I assumed that the control surfaces have been removed. A new neutral point is then found by computing the normal lift distribution based on the wing chord minus the control surfaces. This neutral point must also lie behind the c.g. The result is stability not only with the stick fixed but also stick free; also control movement stability in that each stick position corresponds to a distinct C ; and finally both aspects of control force stability--for instance in steady flight as in a turn the force increases with increased C , and with constant acceleration there is decreased dynamic pressure at higher lift coefficient, as in landing. There, however, again because of ground effect, control force increase is not certain.

Landing aids are very important for the moment balance of a flying wing. In 1936 I chose for the H V a combination of split and hinged flaps extending to 0.5 semispan and was thereby able to increase the maximum lift coefficient to about 1.8. There remained however a slight nose-heavy moment which could be balanced by an elevator deflection. In 1938 I built a 90-degree split flap extending to 0.12 semispan into the H IIIb; designed as a brake, it nevertheless produced very strong lift and a tail-heavy moment. The moment and lift were reduced again by an additional spoiler on the upper surface of this region; the braking effect was not affected. Dr. Krashinsky in Argentina has again studied this question in a wind tunnel and found that a flap extending only 0.15 of the semispan must suffice to increase lift 60-65% without producing a moment. He therefore recommended for sailplanes a kind of Fowler flap in this zone to allow the plane to fly slowly through lifting air while creating a slight tail-heavy moment similar to an elevator deflection. On the strength of this a test with a Junkers type auxiliary airfoil was improvised with the two-seat I. Ae. 34, which Scheidhauer flew with Nickel as observer.

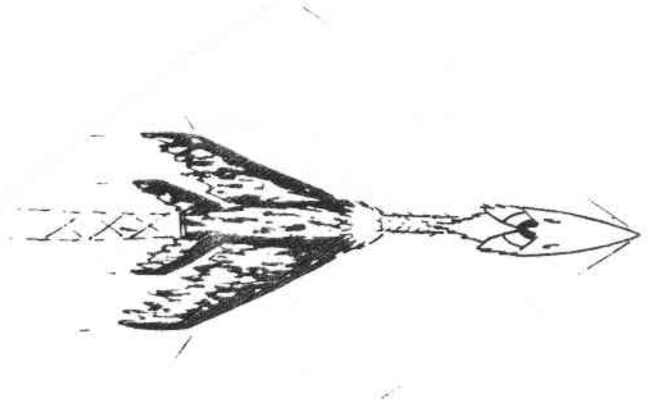
Concerning dynamic stability it should be mentioned that the moment of inertia of Delta wings about the lateral axis is higher than that about the longitudinal axis; the opposite is true of large-span sailplanes. For these, movements about the lateral axis are faster, an advantage in dolphin flight. The rotational damping of a swept wing is about a third that of the horizontal stabilizer of a conventional airplane of similar size. Because the c.g. range, and hence the static stability, can be kept small, the phugoid oscillation is usually aperiodic, hence trouble-free. This however requires a stiff airplane.

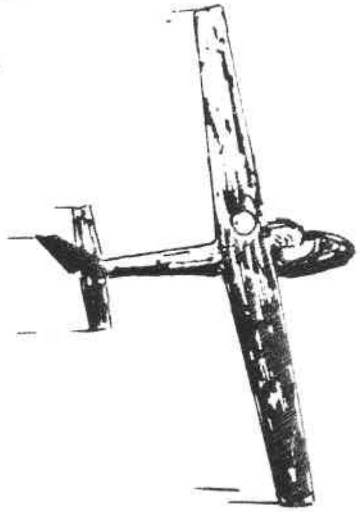
A new phenomenon made its appearance on the H IV and H VI: wing bending. Because of the sweep, it causes a change in wing washout in the outer panels, and during oscillation of the wing it produces a periodic change in washout, which in turn causes a change in flight path. This could not be flown through using the controls, but the critical speed could be displaced to higher values by extending the drag rudders on both sides. Reinforcement of the center-section and lightening of the tips to raise the fundamental frequency of oscillation caused no visible improvement. Dr. Haener in Argentina studied the problem mathematically in 1956 with the result that only the outer wing panel is significant, not the fundamental frequency, and the stiffness of the wing region around 0.6 semispan is critical. In this way, Dr. Haener solved the problem of critical speeds in high aspect ratio all-wing airplanes.

Cordoba, September 1982

[signed]
Reimar Horten

Translated by Francois-Marc de Piolenc, April 1986



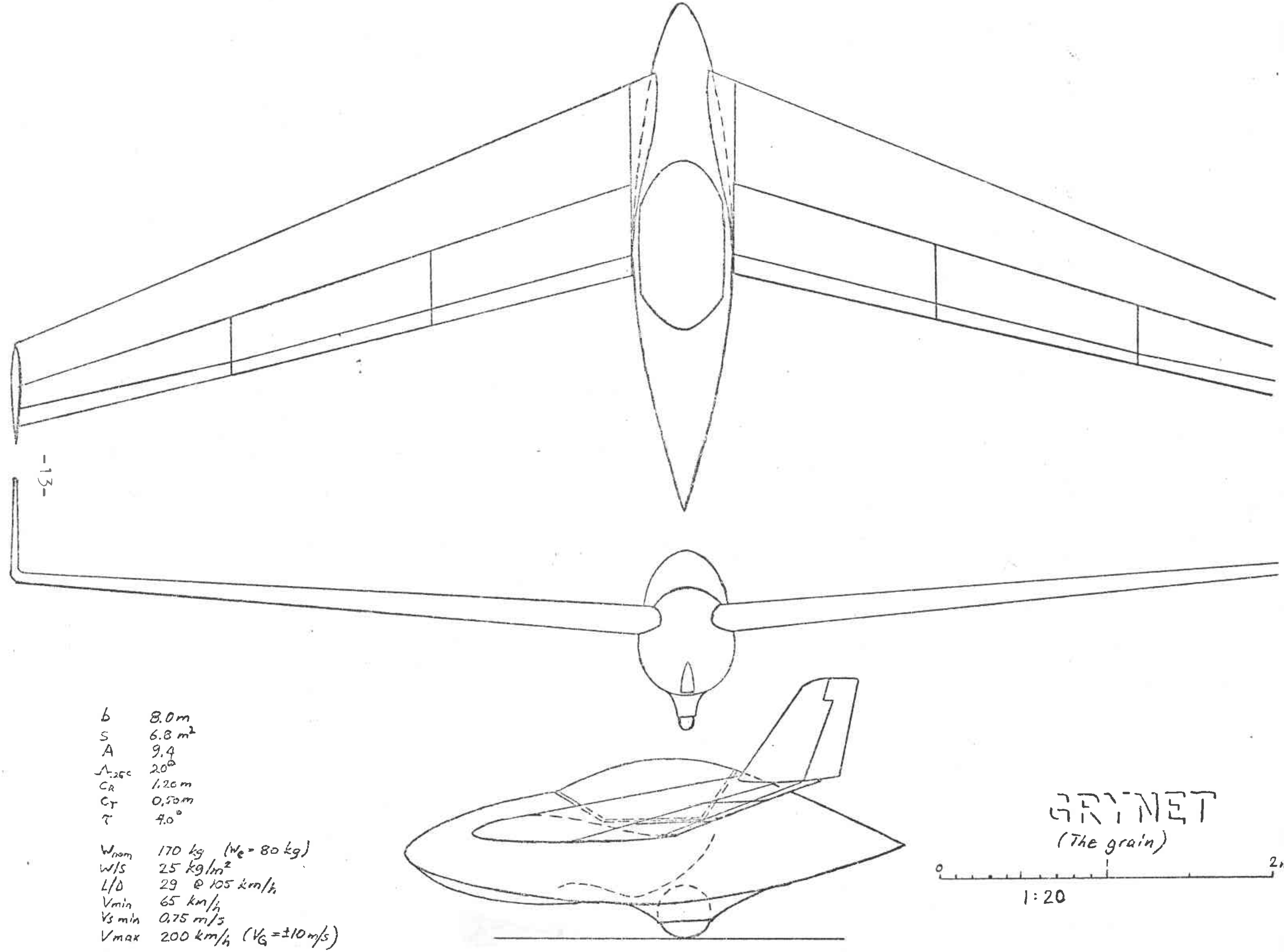


Here are two interesting designs by Ben Jansson who together with Hank Thor built the beautiful little wooden ship which Hank now flies. Ben is back in Sweeden working for SAAB. The outstanding feature of the flying wings are the full span 50% chord flaps which have a linked trailing edge segment which remains parellel to the wing chord as the flap goes down. Ben found some old NACA data on large chord ailerons with tabs which indicated that such an arrangement gave a good lift increment without an attendent nose down pitching moment.

The 8 meter design is to be a minimum size, minimum weight, low cost sailplane with acceptable cross country soaring performance. The 18 meter ship is for very high performance.

Ben wrote that he has quite a time getting around to even writing a letter much less an article. However, if we publish these plans with the above terse comments he might just come through with a good paper on the design problems in time for Marfa. At any rate I think novel designs of this type even if not in the flying stage are a good stimulus to the soaring world.

I have corresponded with each of the seven contributors anywhere from 3 to 6 exchanges of letters and feel that the enclosed is all I am likely to squeeze out of them at this time. I am sorry I could not have put all this in better form before I became ill. I felt it better to send what I had on to you since much of it has been sittin around here gathering dust since late fall. Feel free to write or phone me if specific questions come up. Where details do not appear clear they can probably be removed. Since each of the 7 made an effort to provide the enclosed I feel we should publish something

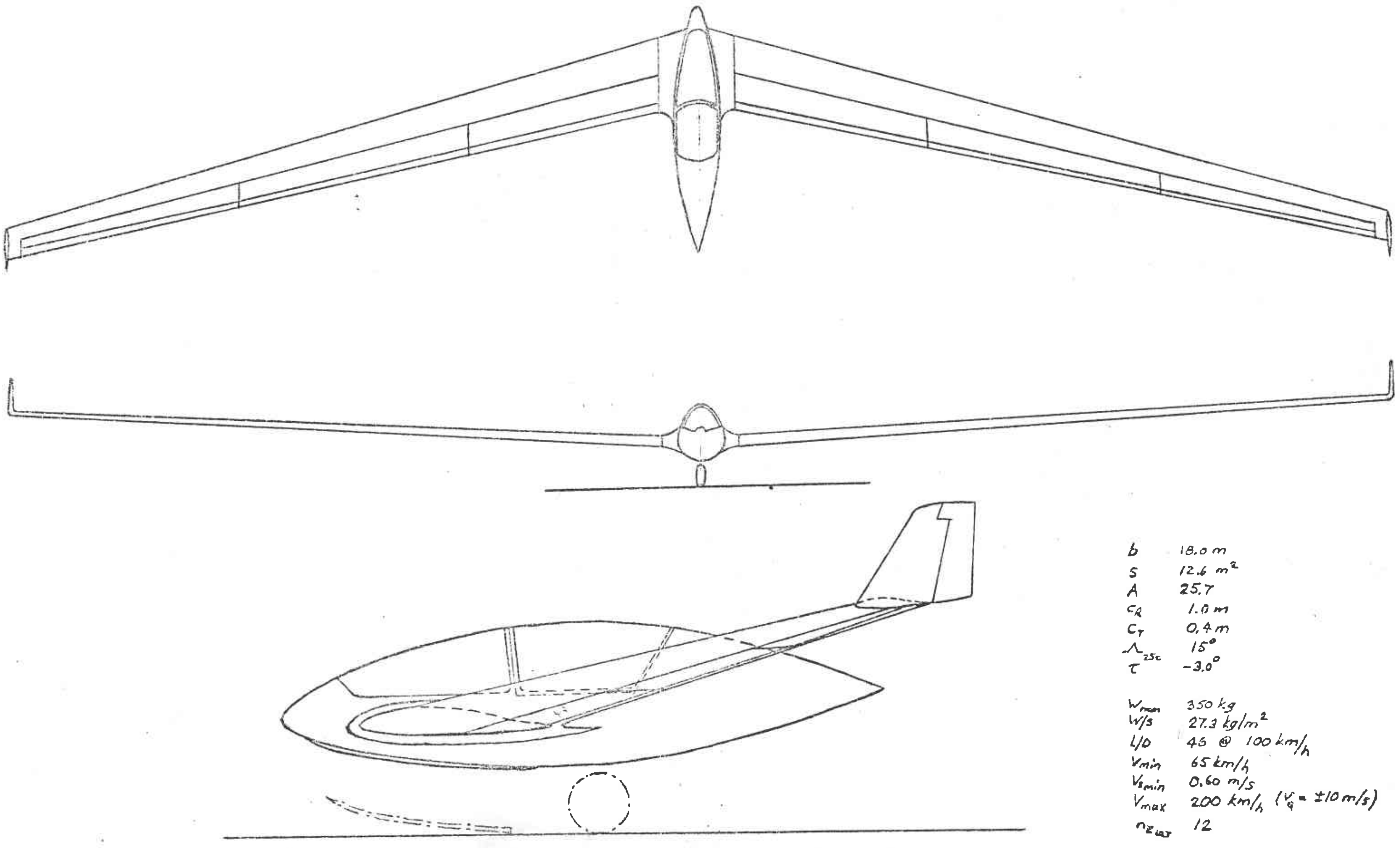


b	8.0 m
S	6.8 m^2
A	9,4
$\Lambda_{.25c}$	20°
c_R	1,20 m
c_T	0,50 m
τ	4.0°
W_{nom}	170 kg (W_e = 80 kg)
W/S	25 kg/m^2
L/D	29 @ 105 km/h
V_{min}	65 km/h
$V_{s\,min}$	0,75 m/s
V_{max}	200 km/h (V_G = ±10 m/s)
$n_{z\,ult}$	12

GRYNET
(The grain)

23-10-68 B. Jansson

This high performance should possibly have 4 flapsegments instead of 3 to give a smoother twist distribution. Aileron deflection like Horten IV by using two sections might also be a good idea (Described in OSTIP Pub. no VI)



b	18.0 m
S	12.6 m^2
A	25.7
c_R	1.0 m
c_T	0,4 m
Λ_{25c}	15°
τ	-3.0°
W_{max}	350 kg
W/S	27.3 kg/m^2
L/D	45 @ 100 km/h
V_{min}	65 km/h
$V_{s\,min}$	0.60 m/s
V_{max}	200 km/h ($V_G = \pm 10$ m/s)
$n_{z_{ult}}$	12

03-10-68 B.

Test flying a Tailless Ultra Light Aircraft.

by Tasso Proppe

To help understand the basic elements of concern, I have to come up first with a simplified definition for Stability:

If a system ("airplane") in a steady state condition ("flying straight and level") is disturbed (by a gust or a deliberate control input, say, in pitch), stability forces within the system are supposed to develop to bring the system back to its initial steady state condition.
In the pitch axis of an airplane, it works like this: The C.G. (Center of Gravity) of the airplane is always in front of the Center of Lift of the wing. this nose-down moment is compensated by a down force generated by the "stabilizer" aft of the C.G. which therefore has to have a negative angle of attack and it has to have a lever arm ("tail"). - Fig. 1.
If the steady state condition is disturbed, for instance: a gust pitches the airplane nose-down, it will pick up more speed. The stabilizer down-force (a square function of speed) increases, thereby forcing the tail down and restoring the original angle of attack and speed condition.

" Elevator control" means changing the effective negative angle of attack somewhat to establish a different steady state speed, or compensate for changes in C.G. location due to different loading.
"Trim" is a means to coax the elevator into a position which establishes the desired angle of attack/speed balance. This can be achieved by little tabs on the trailing edge of the elevator flaps, or by rubber bungies, or by shifting your weight. i.e. modifying the initial C.G.-to-lift balance.

Tailless Pitch Stability.

These basic principles are valid on tailless airplanes just the same. Since they do not have a tail, the speed-generated down force has to be produced by other means.
The up-swing trailing end of a "reflex" airfoil section (Fig. 2) furnishes such a stabilizing down force, and on swept wings, the negatively twisted ("wash-out") outer panels of the wing provide the same stabilization (Fig 3).
The Minibat with its foreward sweep employs flaps at the aircrafts center aft of the C.G.; the Mitchell Wing (12° sweep-back) uses Junkers flaps, trailing aft and below the trailing edge of the wing outer panels (Fig. 4)
All of them have a pitifully short lever arm.
That's life without a tail.... : A very narrow margin of tolerable C.G. location foreward of the Center of Lift.
A conventional (tail-endowed-) Ultra Light with 400 lbs gross (200 lbs empty plus 200 lbs pilot, fuel, chute etc) and a C.G. location 3" fwd of the Center of Lift would require 10 lbs down-force on a 10 ft tail (120") = 1200 in-lbs = 400 lbs x 3". That would balance it in a steady state condition.
On a tailles airplane with a 48" lever arm from the C.G. to the stabilizing surfaces, the 1200 in-lbs would require a 25 lbs down-force.
On the tailed plane, the angle of attack of the stabilizer is in the order of ½ degree, and it is some 3 degrees on the "elevons" at the outer panels.

To balance a C.G. shift of 1 inch (caused by a heavier pilot or added accessories) would require an insignificant change of the stabilizer's angle of attack, but it would present a problem on the (2) and (3) configuration airplanes, and (4) is not much better off: the required flight angle of the "elevons" changes by several degrees, and it will soon run out of available control range - more so, if those flaps are serving as ailerons as well via the mixer box.

If you happen to read zero or plus (flap down) angles, it means trouble, too. Your C.G. is too far aft. The stability feature I explained at the beginning disappears. There is no more restoring force to the initial steady state condition, the airplane has to be balanced like a broom in the palm of your hand.

That, in itself, is no big deal. We do that on bicycles, too, after acquiring a little skill. In the early thirties, we flew airplanes that way without much ado. But : If you ever get into a stall/spin, the ship will spin flat and stay that way. Just approaching stall, the stick suddenly decides to flair out on its own if you don't watch out.

Propeller Thrust :

A tailless airplane doen't have a propeller blast on the elevator.

Remember: the stabilizer has a negative angle of attack (or better: of incidence). With increasing power on a conventional airplane, the down force increases (a nose-up moment into climb), and at engine idle, this moment disappears and the airplane drops its nose, thereby maintaining speed.

The tailless airplane doesn't do that. Furthermore, the propeller thrust line passes above the C.G. So, with increasing power, it has a tendency to nose down a little, and at idle (on final approach), it slows down (nose up). If you are already tail heavy (our last example, flaps between zero and plus 5° down at normal flight), your airplane slows down too much on approach, and you run out of foreward stick to correct it.

You do not normally die from all this; I have flown some crummy airplanes in my time and experienced these phenomena in various stages of seriousness and scare; but I have lived to tell you about it.

Nevertheless: I think you should be aware of the technology behind all this. And you should do something about it, if you are outside the limits of these parameters.

In Summary :

Measure where your control surfaces are in flight. Shift your C.G. to bring them into an acceptable position like 3° to 4° degrees up !

Trim :

Once that is done, add trim tabs to the control surfaces to make them float into that position - you must be able, in still air, to let go of the stick with the airplane holding its steady state speed condition on its own for a few seconds. This presumes that you have already weight-balanced the flaps; otherwise, they droop by their own weight, causing a nose-down moment even on an otherwise properly balanced airplane.

I found this subject of flight balance to be rather unknown and neglected. Without proper balance, the performance of the machine is considerably impaired and the bird becomes accident-prone.

Take-Off Angle of Attack :

There is yet another flight test problem peculiar to tailless airplanes which actually should be solved before attempting to fly parallel to the ground: The angle of incidence with which the airplane speeds down the runway to get airborne.

Before the invention of tricycle landing gear, tailless airplanes had to be launched from rails or catapults,.

Without a propeller blast on rudder and elevator, you could not control yaw and pitch during ground run on the then common tail-dragger versions.

Yaw is now controlled by the steerable nose wheel - but the pitch angle of the wing is only determined by the position of the wheels.

Center of Lift :

So, we ought to know where the center of lift actually is. That's the most important question.

The wind tunnel data that comes with the airfoil section's "coordinates" is very specific: it tells you where it is (in % of chord) and which way it moves as a function of angle of attack and how much.
But a wing is a combination of a number of design features: taper, twist, and a limited span with its wing tip vortex - they all contribute to the spanwise lift distribution. This, together with a swept back plan form, requires a bunch of aerodynamicists to set up a computer program and then have a computer figure out where the center of lift is expected to be. The computer does not take into account your own built-in variances to the airfoil, the twist, and other human-caused inaccuracies.
A company that builds wide-bodied airliners can afford the computer and the aerodynamicists (maybe not anymore), the homebuilder uses approximations with common sense estimates and assumptions and comes up with a hand-computed lift location - plus-minus 3/4 of an inch, and that accuracy isn't good enough for a tailless airplane.
However, it is good enough for the first hops straight down the runway (but certainly not for aerotows).
The center of gravity is determined by conventional methods; that, too, often turns out different from what the plans called out (if they mention it at all), but it can be measured and computed before the first flight (do I have to explain how ?)
If your "estimated" lift location is about 2 to 3 inches aft of the measured C.G. (with the pilot in it, please !), you are alright for the first test hops.

Measuring the Aerodynamic Balance :

All you have to do now is to find out what angle of the stabilization surfaces you have to fly to keep the airplane level.
The U-2 is a good example to illustrate that: make two templets from a rib drawing closest to the aileron/elevator flap. Extend the chord line beyond the trailing edge, and draw a line parallel to it through the hinge point of the flap (Fig. 5). This is your zero flap position. With a protractor, mark 5°; 10°; 15° lines through the hinge point (and maybe +5° and +10° down, also).

In the cockpit, attach to a fixed point on the instrument panel a stiff strip of metal (like a tape measure) over the range of control stick fore-and-aft motion; have two people hold the "elevon" flaps (or "stabilators") at the zero; 5° etc. position and mark off on the metal strip in degrees these positions so that you can read the markings in flight.
On your first straight hops, after you got the feel for the landing flair-out, fly a stretch of straight and level flight and try to read where your stick is. If that is more than 4° up (stick back), your machine is too nose heavy. If it is about 10°, you can still fly a pattern around the airport, but don't try anything fancy like high speed runs. Your elevator flaps are already too high up and beginning to act as air brakes. If you need more up elevator for any reason, your flaps are approaching stall and they are liable to reverse the intent i.e. stick back becomes "nose down".
If you read, on your straight hops, elevator positions greater than 10°, quit flying, go home and move your C.G. AFT by any means available: shift the pilot further back, add more weight to the engine, move the engine further back (assuming the engine is a pusher in the back - I havn't seen a tailless airplane yet with a tractor engine).

This pitch angle between level ground and the main wing chord line should be the angle of attack at best climb. (Fig 6)
If that is more, the airplane develops more drag and tries to get airborne in a stalled condition (that just doesn't work).
If it is less, you have to run faster to develop enough lift to carry your gross. Apart from a long ground run, you are automatically applying back stick (which accomplishes nothing, since the up elevator only produces a down load on the main wheels).
When the airplane finally works up enough speed to produce lift equal gross, at the small angle of attack, the bird becomes airborne alright - with excessive speed and the sensitive stick pulled back. Your are riding an bronco, and it takes some time for an intrepid pilot to get used to that.

Again, you need a computer to determin the angle of attack for best climb, however, a good guess is 3 to 5 degrees. If you hit it right, the airplane lifts off without you noticing the transition except for a side drift in slight cross wind conditions.
For this purpose, it is wise to provide for some adjustment capability (like 1 inch shim blocks under the nose wheel attach point) to be able to experimentally determin the most comfortable take-off position.
Foreget about airliner type "rotation" - that only works on tailless airplanes with not enough load on the nose wheel (i.e. the main wheels too far foreward)

If you disagree, let me know.

If this treatise helped you understand the subject a little more, let me know, too.

ABOUT THE AUTHOR

We thought you might want to know some of Tasso's qualifications (bearing in mind that this c.v. has been abridged to save space!).

Tasso PROPPE, born August 1910 in Germany, has been "helping people glue gliders together" since 1927.
1934: Silver C international number 33
1935: President of Akaflieg Stuttgart
1936: M.S. Aeronautical Sciences
1939: Chief Instructor, German Engineering Test Pilot School with a German aeronautical test center
1942: Chief, flight test department, Aeronautical Research Inst.
1946: Technical manager and gliding instructor for British forces recreational gliding school, Oerlinghausen, Germany.
1946: Instructor in math, physics, stress
1953: Instrumentation systems engineer, USAF missile test centers
1956-1975: GD/Convair; systems engineering, safety, maintenance engineering; missiles, spacecraft and aircraft systems
1971-1974: Wrote articles for the magazine Motorgliding
1975-: Articles for Sport Aviation, Ultra Light Aircraft Aircraft Journal...

OK?

AGENDA OF THE FOURTH MEETING 27 SEPTEMBER 1986

The next TWITT meeting will take place on Saturday September 27 1986 at hangar A-4 Skid Row Gillespie Field.

We will review out design goals a glide ratio of 40 and a minimum sink of 1.2 ft/sec. The first goal can be exceeded and the second can be met! We have chosen composite construction. The exact method of fabrication--molded or moldless (Rutan)--remains to be decided. The center section cannot be designed until we choose a pilot position. The trim method--whether variable wing sweep. a movable weight or some combination of these--will be incorporated into the center section. The aspect ratio, thickness and plan form can now be selected. The active control system and the above design can now be built in hang-glider form and test flown. A quarter-scale model could also be built to evaluate different configurations. We have lately published 3-views and data (sometimes including polar curves) on various flying wings. We will discuss this information as part of our future agendas. We also need someone to identify the small swept-back tailless machine that appeared on the cover of our first issue.

ADVANCE NOTICE

The October TWITT meeting will take place on the 18th, at the same location and hour as before. We are moving the date so that Vern Oldershaw can travel from Bakersfield. Vern is already booked on the fourth Saturday of each month.

Irv Culver is retired from Lockheed's "Skunk Works." He is by his own admission "the world's greatest flight dynamicist," a leading aerodynamicist and authority on vibration and flutter. He has agreed to join our discussion group. While Irv has reservations about the merits of flying wings, he is willing to share his considerable knowledge to help our project.