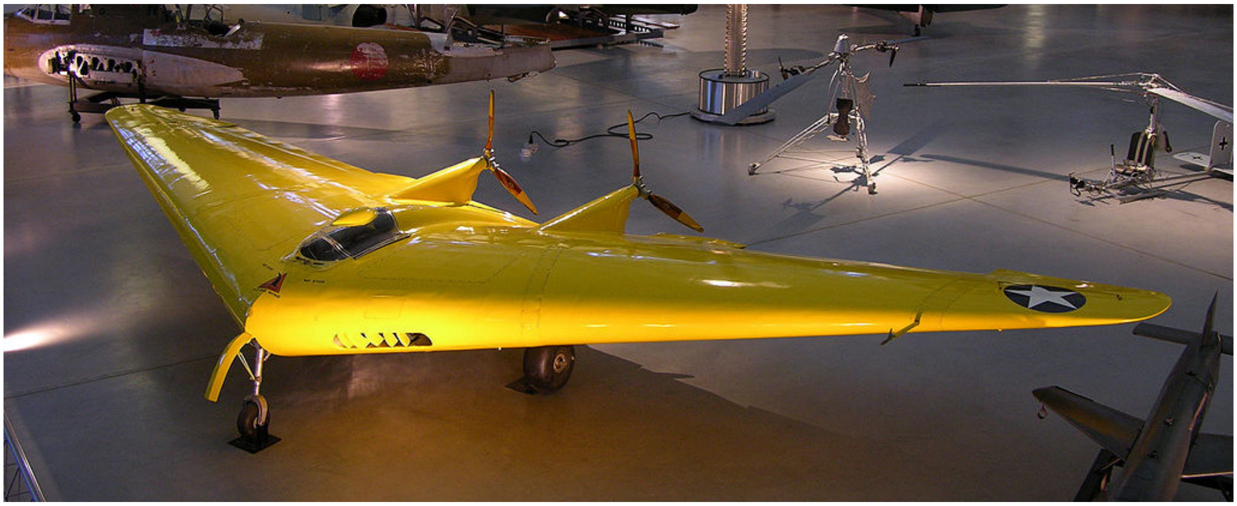
No. 352 OCTOBER 2015

T.W.I.T.T. NEWSLETTER



This is a nice shot of the Northrop N-1M on display at the National Air and Space Museum's Steven F. Udvar-Hazy Center Source: https://en.wikipedia.org/wiki/Flying_wing - /media/File:Northrop_N-1M_Udvar-Hazy.jpg

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

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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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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

In the August issue I mentioned I would be posting a dynamic soaring paper from Phil Barnes in September, but then that issued became dedicated to Bruce Carmichael. So this month I have started Phil's paper and will finish it up in November. I just didn't have enough pages to get the entire paper in this month but did find a nice piece to finish off the remaining pages.

I know some of you aren't members of the Nurflugel Bulletin Board on-line system, so I decided to download the article on flight testing a Horten X and including it for your reading pleasure.

I am hoping to get a flight test report from Mike Hostage on his Pioneer III sometime in the near future. I also have a piece by Jim Marske on the Backstrom planks with some information on the Pioneer series that will be coming up in future issues. This is the first time in a while that I have had enough material to cover several months in a row and I am enjoying it.

However, don't let this stop you from submitting your pictures and articles of your projects. It is always nice to have too much material since it is usually not time sensitive.

I hope everyone had a great summer season and got lot of flying your models or sailplanes. I didn't get as much as I would have liked, but fortunately southern California is generally flyable year around.

Andy

Dynamic Soaring Update

J. Philip Barnes, Technical Fellow, Pelican Aero Group, San Pedro, CA 90731

This article, specially prepared for TWITT and ESA members, includes adapted excerpts from Phil's latest AIAA paper 2015-2552 "Aircraft Energy Extraction From an Atmosphere in Motion" and updates Phil's "landmark" (per Bruce Carmichael) 2004 study of dynamic soaring by describing more-recent wind and wind profile data, adding new insight into the physics of dynamic soaring, updating the "snaking upwind" maneuver, and introducing the possibility of Jetstream dynamic soaring.

I. Nomenclature (S.I. metric units)

A = wing aspect ratio
c_L = lift coefficient
c_D = drag coefficient
D = drag
E = total specific kinetic and potential energy
F = dynamic soaring force
L = lift force
m = mass
n_n = normal load factor, L/W
n_t = tangential load factor
q = flight dynamic pressure, $(1/2)\rho V^2$
S = wing planform area

V = velocity (airspeed)
w = windspeed
w' = wind gradient, dw/dz
W = weight
x = distance directly downwind
y = horizontal distance normal to wind
z = vertical coordinate
γ = flight path angle
φ = roll (to right) angle about velocity vector
ρ = air density
ρ = wind probability density
τ = time/period
• = heading angle (=0 upwind)

II. Introduction

ENERGY for sustained flight can be gained by intelligent and/or optimal motion of an aircraft within an atmosphere which is itself in motion, provided certain conditions. Dynamic soaring aircraft (DSA) will soon emulate flight techniques perfected over for millions of years in the natural world perhaps by Pteranodon (Figure 1) and most certainly by the albatross (Figure 2). Specifically, the energy is gained by smart maneuvering within the vertical gradient of horizontal wind. We show why the albatross has been endowed with high lift/drag ratio and high wing loading, and why a Jetstream DSA (Figure 3), if proven feasible, must also have high L/D, but must also fly at the speeds of today's commercial transports.

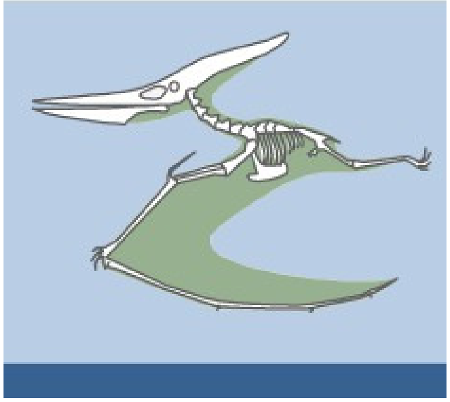


Figure 1. Pteranodon

Figure 2. Albatross

Figure 3. Jetstream DSA

The historical basis for our present study begins with the work of Lord Rayleigh (Figure 4), who was first to explain 1 qualitatively the principles of dynamic soaring. A contemporary paper by Boslough 2, and our own paper 3 which was authored unaware of these two earlier papers, yielded by quite different methods similar formulas for dynamic soaring, and these quantified and validated Rayleigh's description. All three analyses used airspeed, not inertial speed, to characterize flight kinetic energy, and all three showed the fundamental importance of the wind gradient to the dynamic soaring phenomenon. At least two recent papers4, 5 used GPS "bird-backpack" inertial speed, in effect groundspeed at the shallow flight path angles of the albatross, to characterize the flight kinetic energy of dynamic soaring maneuvers. This oversight led those authors to conclude "the wind gradient itself is of insignificant influence" and "the energy is achieved in the upper part of the [trajectory]." Our study shows instead that the bird gains its energy at the lower part of the trajectory where the wind gradient is pronounced, first with the upwind climb, and again with the downwind dive. Herein we further reinforce Rayleigh's original assessment, and apply what we have learned to suggest basic criteria for the feasibility of Jetstream dynamic soaring.

Figure 4. Lord Rayleigh
Wellcome Library, London

III. Dynamic Soaring

The wandering albatross uses its dynamic soaring technique to remain aloft indefinitely on shoulder-locked wings, progressing in any overall chosen direction. Of course, the albatross frequently takes strong advantage of ocean wave lift, but as shown in our original study3, the bird travels overall downwind much faster than the wind, leaving the waves far behind as it circumnavigates Antarctica several times per year. Lord Rayleigh was first to accurately describe the essential principles of dynamic soaring, and we next illustrate several of his observations, drawing from our own work published without prior knowledge of his work. To quote from his seminal paper, with permission from Nature Publishing Group:

> "...the available energy at the disposal of the bird depends on his velocity relatively to the air..."
>
> "...let us now suppose that above and below a certain plane there is a uniform horizontal wind, but that ascending through this plane the [wind] velocity increases..."
>
> "... in passing through the plane...the [bird's] actual velocity is indeed unaltered, but the velocity relatively to the surrounding air is increased."
>
> "... it is only necessary..to descend ... moving to leeward, and to ascend ...moving to windward."

These principles are illustrated by Figure 7 where a model aircraft held beneath the moon roof of a moving car is released either above or below the moon roof. This not only shows the reliance of flight on airspeed, but also shows the essence of dynamic soaring whereby airspeed (the speed "relatively" to the air) is suddenly increased by climbing upwind into stronger headwind. In the companion process, which may be for some more difficult to grasp, the bird also gains energy upon downwind descent across the same threshold. Once dynamic soaring in a two-step wind profile is understood, we can more readily see that a series of smaller such steps in the form of a continuous wind profile will yield the same benefit (Figure 8). Regardless of the number of steps in the wind profile, the bird cannot escape the energy loss due to drag. But for the albatross, such energy loss is matched overall by flight kinetic energy

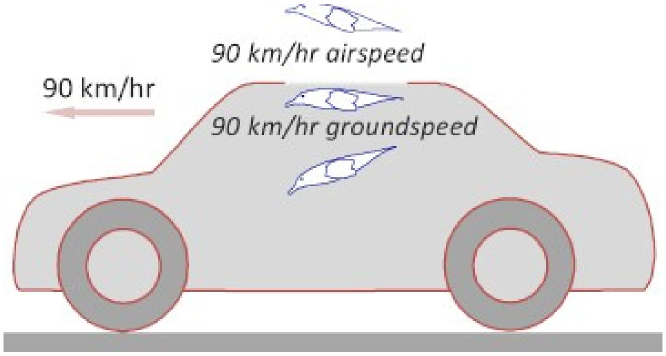


Figure 7. Two-step profile; Airspeed Vs. groundspeed

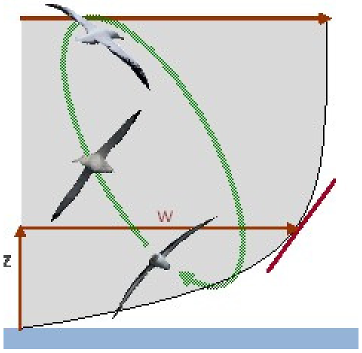


Figure 8. Continuous profile and gradient

gained by dynamic soaring, given a threshold wind gradient, and given the 40-million years of evolutionary optimization which have bestowed upon the albatross the flying skill, wing loading, and wing shape which together match the bird to the wind boundary layer which constitutes its home over water as far as the eye can see.

Figure 9 shows the wandering albatross flying somewhat to windward, with the airspeed vector (V) oriented at a heading angle (ψ), and flight path angle (γ). The bird has rolled to the right about the velocity vector by the angle (φ). Also shown are the forces representing lift (L), drag (D), weight (W=mg), and dynamic soaring force vector (F) which, in our original study3, was postulated to point directly upwind with a magnitude given by the product of the bird's mass (m) and rate of change of wind velocity (dw/dt) per EQ (1). Since the wind profile w(z) is fixed, the only way for the bird to experience a rate of change of wind is for the bird to move vertically within that profile. In EQ (2), the portion of dynamic soaring force aligned with the airspeed vector yields the dynamic soaring thrust. Notice the similarity of EQ (1) to Newton's Law. Here, some readers may object to the proportionality of the dynamic soaring force to the bird's mass (m), but we note that the bird flies within two gradients, one being gravity, representing the vertical gradient of potential energy, with its force as well proportional to the bird's mass.

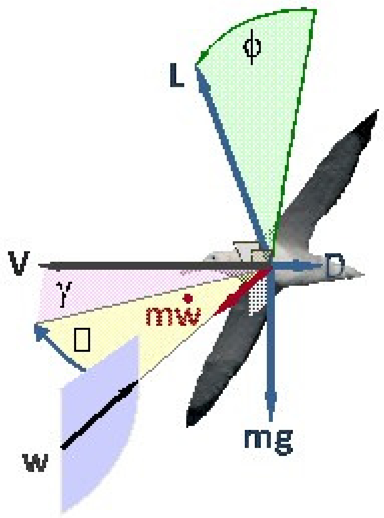
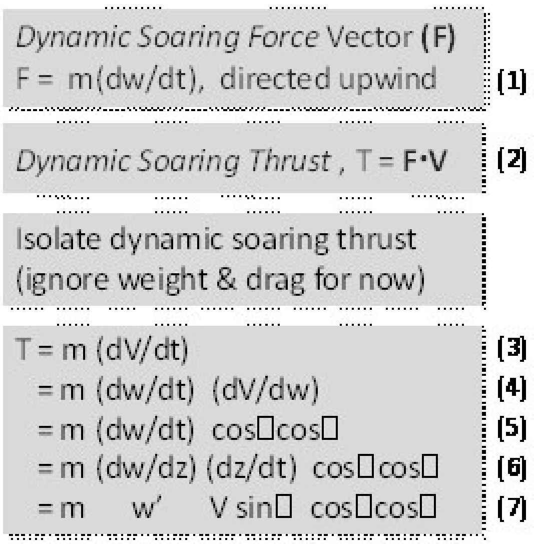


Figure 9. Angles and Forces



Dynamic Soaring Force Vector **(F)**
F = m(dw/dt), directed upwind **(1)**

Dynamic Soaring Thrust , T = **F·V** **(2)**

Isolate dynamic soaring thrust
(ignore weight & drag for now)

T = m (dV/dt) **(3)**
= m (dw/dt) (dV/dw) **(4)**
= m (dw/dt) cos□cos□ **(5)**
= m (dw/dz) (dz/dt) cos□cos□ **(6)**
= m w' V sin□ cos□cos□ **(7)**

Figure 10. Dynamic Soaring Thrust Derived

With the aid of Eqs (3-to-7), we now derive (Figure 10) what we had previously postulated. If, for the purpose of the present derivation, we put aside both the weight and the drag, the acceleration (dV/dt) along the flight path is related to the dynamic soaring thrust (T) via Newton's Law as in EQ (3). Note that (V) represents airspeed, not groundspeed. Applying the Chain Rule of Newton's and Leibniz' calculus, we relate the rate of change (dw/dt) of windspeed to its vertical gradient (dw/dz) in EQ (4). Any change of airspeed is related to the change of windspeed in accordance with the "alignment cosine product" of EQ (5). Again applying the Chain Rule, the rate of change of windspeed is expanded in EQ (6). Finally, we apply shorthand to define the vertical gradient (w'=dw/dz) of windspeed and, noting the equivalence of climb rates (dz/dt) and (Vsinγ), we obtain EQ (7) which is seen to retain the proportionality to mass (m). Let us next digest the extensive information revealed by EQ (7).

We see from EQ (7) that the dynamic soaring thrust is proportional to the mass (m), wind gradient (w'), and airspeed (V). Thus, the albatross has been endowed by nature with a much higher wing loading than that of a thermalling bird such as the great frigate bird (which has the lowest wing loading of any soaring bird). For the greatest dynamic soaring thrust, the albatross must penetrate into the wind profile at high velocity and at some optimal flight path angle (γ) which depends in part on the heading (ψ). Here we note that the dynamic soaring thrust remains positive when the bird descends downwind, whereby both the flight path angle and heading cosine go negative as the profile w' ≡ w(z) remains fixed. ***(Continued next month)***

NURFLUGEL BULLETIN BOARD

Rummaging through the back of a riotously disorganized secondhand book shop the other day I unearthed a random selection of back issues of Sailplane & Gliding from the late 1940s and early 1950s, amongst which was a report of aero towing the 7-5 meter Horten X. I can't recall having seen this before so it may be new to some people. It has been uploaded to Nurflugel files under the above title as a PDF file. I hope interested Nurflugel members can all read it. In it there is reference to an earlier report which I am sorry to say I have not got.

Chris Bryant

(ed. – Since some of our members don't have access to the Internet and/or the Nurflugel website, I have included the report posted by Chris.)

TEST FLIGHTS OF THE HORTEN-X

by Rogelio Bartolin!

***Sailplane & Gliding* March/April 1955**

In an earlier issue I told you about our first trials of the 'Flying Winglet' —now I propose to tell you something of our first aerotows. On the 2nd May Tacchi, Figueros and I met at J. Celman and got everything ready. A few days earlier we had fitted a parachute, a Switlink, extra flat, back-type, with the harness fastened to the envelope with two clips. This envelope is attached horizontally to the fuselage by two rubber bands, just behind the longeron and below the plywood strip forming the join in the centre of the wing. To the parachute harness we have added two straps which join and terminate in a clip. When the pilot gets in he fixes this to a safety-clip on the chest-rest. To get out of the cabin the pilot only has to turn a catch and he is freed, but as the main part of the parachute remains fixed to the sailplane it is necessary each time he enters the cabin to attach the two clips of the harness to the rings of the parachute.

As well as the air speed indicator we have now fitted a variometer, but both were directly connected to the cabin in a manner that we have since learned made them rather unreliable. We did it like this because Dr. Horten had explained to us that otherwise to get a good static pressure we should have to fit a tube that would project more than a metre from **the** front of the leading edge, owing to the large chord of the wing.

We also fitted a chin rest. This is important, because without one the neck muscles soon tire a few minutes after taking up a prone flying position.

Everything was ready and we went out on to the field. Eynard was ready to launch me, so after agreeing our take-off procedure, I settled myself into the cabin and signed that I was ready. The rope tightened, we began to slide over the ground, the speed crept up till the controls began to respond and immediately we took off. Speed increased until the 'Fleet' also took off. From now till the moment of release there is little to report for the launch was perfectly normal, as indeed were each of the succeeding ones. By this I mean that there was nothing more noticeable than there would have been with a 'Grunau Baby'. Only two things were different—one, the prone position, and the other the speed of ascent, which was notably faster than that of a 'Grunau'.

The controls responded excellently and I could go wherever I liked with a slight movement of the stick. The speed of the launch was between 80 and 90 km./h.

The prone position is comfortable enough. Up to now we have only done flights of half an hour (from the time of releasing) so that it is not possible to report on this very fully. On the first flight the chin rest was a little loose and when I leant on it **I** could no longer see the tow plane, which stayed below the horizon throughout the launch. To see it I had to hold my head up and this was tiring. In later flights we lifted the chin rest a little and all went well.

As I had no altimeter I had arranged with Eynard to give me a signal to release when we got to 800 metres, so when I saw his sign I released. I tried her in level flight at speeds from 50 to 100 km./h. and all went splendidly. The controls were easy and she responded a t once. There was no tendency t o turn or to bank to either side. Only when I flew around 100 km./h. did the stick tend to go forward.

I tried various turns. In this machine turns are very easy. All you have to do is move the stick towards the direction of the turn and immediately she banks and begins to turn herself. This synchronization obtained by the Frise effect of the lifting aileron has proved so good that so far it has not been necessary to modify it at all. In a rapid change of direction she yaws a little to begin with but at once settles down.

Visibility is pretty good and has the advantage that one can see directly below through the celluloid aperture in the lower edge of the wing.

After a few more turns I had lost sufficient height to come in and land.

From then on our early aero tows were made in a completely calm air. I would first of all make a trial flight in a 'Grunau Baby' to be sure, and this is necessary in trying out a prototype when one doesn't know how it will behave and especially so when—as in this case—the machine was never intended for aero tow anyway.

My second test flight was on the same day and this time we tried somewhat tighter turns during the aero tow. The chin rest had been placed higher so that now I could see the tug plane without having to lift my head. At 800 metres I cut loose again and built up my speed to 120 km./h. without noticing any vibrations either of the sailplane or of the controls. I then tried out the minimum speed and by pulling the stick hard back I only got down to 50 km./h. which is not really the minimum speed. We will have to increase the possible elevation of the ailerons, for at 50 km./h. the controls respond perfectly and there is no indication whatever of a stall.

Then I tried a slow turn. For this I moved the stick till the inclination was about 30° and pulled her nose up as high as possible. With the stick centered she turned at 60 km./h. quite steadily through five or six turns with no sign of deviation and no need to correct. Each turn of 360° lasted 12 seconds. This time could be reduced by flying at a slower speed but before this we shall have to adjust the ailerons.

All was going well and I decided to try a loop. I dived to 110 km./h. and pulled the stick back gently but it was too gentle and the loop hung inelegantly. I got past the vertical but then stalled and turned rapidly round the transverse axis till the nose pointed vertically downwards. There the turn stopped and she began a dive. As the speed built up I lifted her nose slowly and at 120 km./h. pulled the stick back for another loop. This time one might almost call it a proper loop though she was still hanging a bit. We had tested the main spar in the workshop and it had seemed strong enough but in these first loops I thought I had better go a little gently and not subject i t to too great accelerations, so I did a few more turns and came in to land. On the way in I tried slight inclinations of the stick to right and left; in a machine with coordinated controls like the ‘Flying Winglet' this has the effect of a sideslip such as we practice in sailplanes without brakes.

As the ‘Winglet' has simplified controls these cannot be crossed to sideslip, but if one tilts the stick alternately and definitely from side to side the machine oscillates around the longitudinal axis. If this is done relatively quickly the Frise effect is insufficient to start a turn, but while the general direction is maintained the turbulence set up by the sudden movements increases the speed of descent and is thus equivalent to a sideslip. This is not at all dangerous as I have proved that even when the inclination is over 30° the sailplane is so little crossed as not to be unstable. What one has to watch is the line of flight, because a stall at that angle and height could be unpleasant, just as it would be in a hanging sideslip. In a gusty wind, too, it would be well to come in straight from sufficient height since a gust could place the sailplane in a dangerous position.

A week later—that is to say, on the 9th May—we returned to J. Celman to make a series of comparative flights between our 'Flying Winglet' and a ‘Grunau Baby' with enclosed cabin. An enclosed cabin can improve the angle of glide of a Baby ' from 1:17 to 1:19. Of course one should really be able to make more accurate measurements but ours was rather guesswork, based on some tests carried out in Finland with a ‘Pyk-5,' a machine similar in characteristics to our 'Grunau' In that they had improved the performance from 1:16.5 to 1:19 by streamlining the cabin, so I put the performance of our ‘Grunau' with enclosed cabin at an optimum of 1:18.

This time we took off in double tow, myself in the ‘Flying Winglet' and Eynard in the ‘Grunau Baby’. The tug pilot was Rodriguez. We used towropes of different length, 80 metres for the ‘Baby' and 120 metres for the ‘Wing' so that throughout the tow I was behind and to one side. It was an interesting experience and I was more convinced than ever of the suitability of our machine for aero tow. I only had to move the stick very little to be able to keep my place well to one side of the aeroplane.

Eynard and I had previously agreed that he should release first and that we would do simple glides at set speeds, beginning with the ‘Grunau's' minimum, so at 650 metres he released and I followed. We flew south, 30 metres apart and at a speed of 50 km./h. At once I saw that the ‘Baby' had less sinking speed and was staying above. We increased speed at 10 km. a time but as the ‘Baby' was now above me it was impossible to tell whether the sinking speeds were relatively increasing or diminishing. We got to 80 km./h. and the difference still seemed to be in favour of the ‘Baby'. As we had little height left we separated and I landed a little behind Eynard after he had done a few aerobatics on the way down.

Next I had another double tow, this time with Picchio, and we released at 1,100 metres. This time we did straight glides towards the north at speeds from 50 km./h. to 80 km./h. We flew 30 metres apart as before and again the Baby ' stayed higher at 50 km./h., but this time Picchio side slipped off his extra height and we tried again at 60 km./h. and so on up to 80 km./h. where we had to break off and land.

The third launch was with Eynard again. We released at 900 metres and tested speeds from 80 km./h. to 100 km./h. At these speeds the advantage of the Baby ' had appreciably decreased. When we flew at 100 metres the ‘Grunau' was a bit higher and behind me so I could not see very well, but both Eynard and I thought the difference in height was not increasing.

The last flight of the day was with Rodriguez. We went up to 1,000 metres, started our glides at 100 km/h and increased by tens to 140 k m/h. At this speed my machine flew very sweetly and with no vibrations of any kind, but the tendency of the stick to pull forward had noticeably increased—so much so that I think if I had let go at that speed the glider would have gone into a vertical dive at once.

In this speed range the two machines were on a par, but before drawing any positive conclusions I must point out that these few tests can only give a very approximate idea of the qualities of the ‘Flying Winglet' and then only of the earliest stage of our prototype.

Although the air was calm—a very necessary condition for comparative flights like these—one should really do many more similar tests before drawing any conclusions. Also these should take place from greater heights so as to give more time for comparison, for from 500 to 300 metres one can only continue if the machines are already well placed with respect to the landing strip, and from 300 metres down comparisons are impossible. Roughly we can give our results as follows : Up to 100 km./h. the angle of glide is better in a ‘Grunau' with enclosed cabin, though at higher speeds the advantage lies with the 'Winglet'. This is not really an advantage, though, for it is not worth flying the 'Baby' at those higher speeds over a distance unless, for example, one is in a wide zone of up-currents such as a storm front. However, it did show that the performance curve of the Winglet ' is flatter than that of the ‘Baby' and this is interesting, for our prototype has a fixed skid and also an opening in front of 60 cm. X 80 cm. through which the pilot enters. These two factors obviously affect the speed of descent, since they produce appreciable turbulence. It is evident that one could much improve the performance by closing the opening with a light panel and by fitting some sort of retractable skid, when the Winglet ' should have the advantage at anything over 70 km./h.

As soon as our test flights have finished and we have been granted a Certificate of Airworthiness we will get busy on the improvements. As a result of our first flights we have decided on the following modifications :-

Enlarging the cabin by lifting the curved Perspex so as to allow more movement on the part of the pilot.
Because it was too small Dr. Horten's test pilot, Scheidhauer, could not get into the cabin.

The front part of the curve also should be lowered a few centimeters to improve the visibility, especially on tow.

The windscreen will be redesigned, making it longer towards the back. This will lessen the instability produced by a surface below the centre of gravity when there is a gust of wind from the side.

We must increase the upward capacity of the ailerons so as to be able to fly more slowly, especially in turns.

Dr. Horten tells us that to lessen the tendency to dive that is noticeable at speeds higher than 80 km./h. we must add to the ailerons aluminum flaps 30 cms. wide which will project 6 cm. from the trailing edge and have a downwards inclination of 20°.