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Soaring Digest
December 2022
Vol. 37, No. 12

The New RC Soaring Digest

December, 2022
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In The Air

Snowball, six o'clock high! (credit: Kevin Newton, see 'Winter' below for details.)

The French have a word for it.

I have long admired the French language, especially when it's overheard while savouring an espresso on the Champs-Élysées on an April day. In particular, I love the way the streamlining is built in — the removal of extraneous letters seemingly solely to make it easier to speak it 'trippingly on the tongue'. How the clunky (and wholly incorrect) *le histoire jusque alors*, for example, is naturally transformed into the practically melodic (and correct, I believe) *l'histoire jusqu'ici.* The story so far.

I also love the fact there are words in French, perhaps capturing a certain Gallic nuance, that simply do not exist in the like-a-beat-up-Jeep, utilitarian English. My favourites of all, surprisingly, are the words *neuf* — as in brand new, right off the factory floor — and the word *nouvelle* as in 'new to me': *mon nouveau planeur, par exemple.* In my mother tongue, it's always necessary to add the explanatory 'new to me' when explaining to my wife the presence of a chunky, chalky red *Fox* foamy occupying my work bench for the first time. While *l'Alpenbrise neuf* remains securely tucked away in the rooftop Thule box for the time being, of course.

The French handling of the concept of 'new' is a better one without a doubt.

As the editor of this humble journal I'm always on the hunt for the *neuf* — something brand new — to present to you, the reader. It's a relentless and merciless assignment. Its reward — if I'm lucky — is something you have never seen before and makes you want to say 'I never thought I'd live to see the day…' And there's plenty of cool stuff out there, at least some of which you'll find in the aptly named *Cool New Stuff* section which, in turn, you'll find in the *Launch Zone* of this issue.

Then again, there is also room for *nouvelle* in the New RCSD. I was involved in a conversation a while back about the novelty of a sound, scientific explanation for dynamic soaring — or possibly the lack thereof. As with all things these days Google, the consummate conversation ender, was used to settle the matter at least to some degree. It came as a shock — perhaps it shouldn't — that an authoritative work on the subject by a pre-eminent scholar was to be found right here in the back numbers of the RC Soaring Digest! Therefore, *High-Speed Dynamic Soaring* by Dr. Philip L. Richardson leads off our *Features* section. It's an updated version, though, produced with recent assistance from the author. So while it's definitely *nouvelle*, having appeared on these pages over a decade ago, some additions have transformed it into (almost) *neuf*, I think. And the science it describes, of course, is timeless.

So far as the rest of this issue is concerned I'm exaggerating just a little, but not too much, to say it's too voluminous to comprehensively summarise here. Suffice to say, and setting aside all modesty aside for a moment, it's a truly stunning table-breaker which we at the New RCSD hope you thoroughly enjoy as much as all of us did bringing it all to you.

It’s Winter — Go Outside and Play!

While I realise the concept of ‘winter’ needs hemispherical context, when I look outside and wonder where the grass went and when the pathways will need clearing next, it’s clearly **winter** up here at the home office. It was serendipity, however, that we stumbled on a number of wintry pictures recently and thence, spontaneously, this has become ‘the winter issue’. With apologies, of course to all those lucky enough to live in places where spring is about to slide into summer and the gliding season gets properly underway.

But for those of us who *do* live where snow first makes an initially welcome appearance — which becomes steadily less welcome as the winter grinds on *and on* — I hope you take some inspiration from our friend Kevin Newton’s delightful picture that keys up this *In The Air*. The picture was taken at Bwlch, in Wales during “Christmas 2004… [t]he Mustang pilot is Shane Biddlecome and the ground-to-air snowball menace is Mike Young.” Kevin rightly lamented the fact that the “CAM (Combat Air Models) [have] long been out of business. Damn they were good though!” And I agree. Both about the CAM line and also, that there are lots of great flying opportunities, snow or not. Just remember to bundle up and don’t forget the wraparound, garishly large mirrored Oakleys on your way out the door.

Now I think about it, perhaps there is an opportunity for someone out there to produce a redux of the CAM line and transform it from *nouvelle* to *neuf* once again. I’m pretty sure Kevin would buy one. And I would. How about anyone else? Here are a few more examples to whet your entrepreneurial appetite.

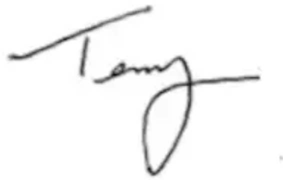
Some beautiful, classic examples of the much-missed CAM line of power scale slope soarers. (credit: Kevin Newton)

Another Year Come and Gone

As I said at this time last year being the “hopelessly lapsed son of English descendants of Irish Catholics”, Christmas is what my family celebrates in December. That said, I also understand that is not everybody’s way of doing things including doing nothing at all. All traditions of this time of year are equally significant and equally worthy of our respect. However, for old time sake and out of respect for my late parents — *this time of year really makes me think of them and really miss them* — I would like to personally wish all of you a very Merry Christmas.

Of course, by the time we meet again, 2023 will already be underway and in this day and age, who knows what that will bring. More than ever, it makes it well worth saying that on behalf of the New RCSD, I simply want to wish for you the very best of health, happiness and prosperity in 2023. And, of course…

Fair winds and blue skies!



Resources

- *[Elf](#)* from Vladimir's Model. — "a new generation of hand-launched planes with 1m wingspan. The amazingly small size of the model gives the pilot access to places he never dared to fly before — car parks, beaches…"

***Cover photo**: We first spotted the exquisite cover photo for this month well over a year ago — but some missed messages at our end meant something else took its place for that particular December issue. You can imagine our delight when we were recently able to re-connect with the photographer Pierre Gumy, who permitted it use now and for which we are truly thankful.*

The almost sculptural picture was taken at Oberiberg in the Swiss Alps in December of 2017. The aircraft is an Elf *from Vladimir's Model of Ukraine (see* Resources*). According to Pierre, it's a modest 100cm span, weighs just 100g and he says "it's a fantastic little plane to fly anywhere in very little wind. It's very relaxing to fly and one of my favourites." Thanks again, Pierre, for the opportunity to feature your beautiful photo.*

You are welcome to download the December 2022 cover in a resolution suitable for computer monitor wallpaper. (2560x1440).

Here's the ***first article*** *in the December, 2022 issue. Or go to the* ***table of contents*** *for all the other great articles. A PDF version of this edition of* In The Air*, or the entire issue, is available* ***upon request****.*

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Letters to the Editor

See if you can spot the one stamp we've added to our montage this month.

No Christmas cards in the mailbag yet, but there were some fascinating letters that came in.

Whither F5B?

What happened to F5B in the US? Back when I was competing in thermal duration contests in the 90's, F5B was the pinnacle in soaring innovation. I still see the planes for sale, but cannot seem to find any competitions.

Raymond Wright
Maryland, USA

Great question, Raymond! But I think I had better let the hive mind tackle that one given that my personal recollection is pretty poor, I'm afraid. What say you, hive mind? — Ed.

Looking for Dodgson Anthem Plans

In the January 2022 issue there is mention of the Dodgson *Anthem.* I like the look of this plane and would like to build one. Can you tell me where I can get a copy of the plan?

Regards,
Norrie Kerr

Thanks for the letter, Norrie. As you already know we had the great pleasure of featuring an extended run of Bob's articles (see Resources*, below). I have it on fairly good authority that he is a regular reader and maybe he can help point you in the right direction. Barring that, perhaps another reader out there can help you out? — Ed.*

The Nippi NP-100 and the Pilatus B-4T

I received a very nice enquiry and subsequent email from a reader in Japan who recognised the plane in Glider Patents *in the October, 2022 issue (it is linked in* Resources*). He had some fascinating recollections of the plane and Japanese General Aviation of the period. — Ed.*

Thank you for sharing the patent information for the *Motor-Glider* in the October issue of the New RC Soaring Digest. I recognised the plane but I did not know they obtained a patent. One that was built and flown with the name NP-100 *Albatross* by Nippi Corp.

I was in the university glider club right after Nippi built and tested the NP-100, and I also had a chance to talk to a person who involved in the project. Nippi is a small aircraft manufacturer who mostly works on Japan and US military aircraft maintenance and repair. They have not had much of a chance to build and fly new aircraft. There was a group of people who wanted to build their own, as an off-work project, and came up with the NP-100.

The NP-100 was tested at Naval Air Facility Atsugi. The story I heard was its climb rate was poor initially. Even with the long Atsugi base runway, it climbed too slowly, getting a bit close to nearby city buildings. Its narrow double wheel main gear seems not be stable, but he mentioned it was okay but only on paved runways. When it was taxing behind an A-4 *Skyhawk* jet and got its full blast, but it did not fall over! That ducted fan intake was not practical against foreign object damage (FOD), especially given most glider airfields in Japan are unpaved.

The NP-100 was demonstrated at local airshow but never got into manufacturing nor did they have a plan for that. I only saw the real one stored at the Nippi factory.

Later Nippi obtained a manufacturing license for the B-4 glider from Pilatus and built 13. They also built one experimental version as B-4T. Our university receive one of the first five built. It is a good sturdy all metal single seat trainer that I flew a lot. That time I had a chance to talk to somebody from Nippi personally and heard the story of NP-100.

The Nippi B-4T was an interesting project. Nippi obtained a design license together with manufacturing jigs from Pilatus. The B-4 structure was quite unique, using thicker metal skin with less internal structure for a smoother surface. It had a modified fuselage, and added a plug in the root of the wing to extend a little with some forward sweep to be a two seat trainer. I heard it is tested at Sekiyado glider field near Tokyo. I only saw it disassembled. It was eventually donated and stored at Teikyo University.

Left: The Nippi NP-100. See links in Resources for more photos. | Right: The Pilatus B-4T license-built by Nippi Corp.

General aviation in Japan is very minor, there are less general aircraft than passenger jet liners. But these two are good memories of people who struggled to build their own plane.

Thanks and best regards,

Satoru Sasaki
Chiba, Japan

Resources

- *The Dodgson Anthology* — The collected works of Bob Dodgson as they appeared on the pages of the New RC Soaring Digest.
- *Glider Patents | US 4,088,285: Motor-Glider* — "In a motor-glider provided with a propeller power system fully encased within the

fuselage thereof, outer shapes of the elements adapted for selectively closing air-intakes…"

Links provided by Satoru Sasaki, with our thanks:

- *The NP–100 Albatross Factory Brochure* — In Japanese, but there are lots of great pictures of the NP–100 *Albatross*.
- *Nippi NP–100 Motor Glider Albatross* — More great pictures of this highly unusual and innovative design.
- *Nippi NP–100* from Wikipedia. — "The Albatross was the first Japanese motorized glider, unusual in being powered by a ducted fan. Design work started in late 1973 and the first flight of the NP–100 prototype was made on 25 December 1975…"

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All images by the author unless otherwise noted. Read the next article in this issue, return to the previous article in this issue or go to the table of contents. A PDF version of this article, or the entire issue, is available upon request.

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F3F World Championship

Søren Krogh from Team Denmark demonstrating near perfect follow-through form.

Hot competition in a cold climate.

The most recent World Championship in F3F was held in Germany back in 2018 and in 2020 it was going to France but a virus threw a very big spanner into the cogs! After postponing the 2020 competition to 2021 it was eventually canceled and according to schedule the 2022 event was held in Denmark. But all is not lost as in 2024 the World Championship will head to France!

Practice session at Vigsø on September 25, 2022.

The dates for the 2022 World Championship in F3F were October 2nd to 8th but the first contestants arrived in Denmark as early as the beginning of September with most arriving the week before to get some practice before the big event. As in previous competitions we would be flying in the north west of Jutland near Hanstholm. A total of 54 contestants from 17 nations were registered, of them two were juniors, Mikkel Krogh Petersen from Denmark and Michał Główka from Poland, and Katja Holstein from Germany who was the solo female contestant.

Practice sessions at Vigsø on September 29, 2022.

As usual there was a pre-contest scheduled the weekend before the World Championship and although it was open for all only 55 pilots were registered as some of the teams used the two days for practice. Saturday started a bit wet so flying didn't start until 15:30 and only one round was flown. Sunday was better and three more rounds were added for a total of four rounds. The fastest times of the rounds were: 48.05, 42.58, 40.34 and 35.02 respectively.

Practice sessions at Vigsø on September 29, 2022.

After finishing the pre-contest a team managers meeting was held by the organisers and later in the evening the opening ceremony of the World Championship was held at the Hanstholm Lighthouse along with a prize giving ceremony for the pre-contest.

Left: Team Norway brought along this Israeli CC tent. Olav Kallhovd, Espen Torp & Bjørn Tore Hagen. | Centre: Team Spain. | Right: Staff and helpers.

Day 1 was flown at the Mors slope which is a low coastal slope, wind was around 10 m/s and was pretty much constant through the day. Five rounds were flown the first day making it a legal competition as four are needed for that. The competition was fierce and both Søren Krogh from Denmark and Thorsten Folkers from Germany managed to win two rounds each. The fastest times were: 37.10, 39.29, 40.33, 41.51 and 39.44 respectively

Left: Grane designed, made and flown by Erik Schufmann. | Centre: Regnar Petersen and Flemming Halkjær inputing data to F3XVault. | Right: Peter Aanen launching.

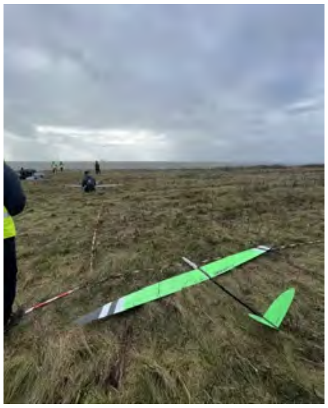
Day 2 was flown at Brunbjerg slope which is inland where thermals can come by and then you better be ready to use the extra power! Four rounds were flown with the sixth round starting off with 4–5 m/s wind and then progressively picking up speed up to about 11 m/s. So for 41 pilots this was a zero round with times from 74.73 to 39.91. The fastest times were: 39.91, 34.50, 34.08 and 33.17 respectively.

Left: Looking over the Brunbjerg slope. | Centre: Espen Torp from Norway and Arjen van Vark from the Netherlands. | Right: Device with a three servo wing.

Day 3 started off very wet so the first pilot briefing was held at the parking lot at 8:30 and then every hour until 10:30 when the day was called off. In the evening there was a social gathering with great food and much mingling plus a technical meeting.

Left: Contestants waiting in a bakery in the local shopping center. | Centre: Jan Hansen CD showing his Spline 2020 project with a one piece wing during the rain break. | Right: Jan Hansen CD with the ballast system for his Spline 2020 project.

Day 4 was going to be flown at a new slope called Kallerup that was only made available for this World Championship. It is a low coastal slope with a very interesting shape. The pilot stands on the edge with the slope going inwards on either side forming a double bowl with the pilot in the center. To say that it was lively would be an understatement as it was blowing around 17 m/s when we arrived and the wind picked up as the day progressed with gusts around 27 m/s. Thankfully the landing area was wide and close to 500 meters in length but it made for interesting approaches as most of the gliders were ballasted at or close to maximum flying weight. Three rounds were flown and the fastest times were: 33.91, 31.15 and 34.22 respectively. Pilots from team Austria split the three rounds between them with Lukas Gaubatz, Philipp Stary and Martin Ziegler each winning one round.



Left: Kallerup slope, note the double bowl shape. | Centre: Respect EVO waiting at Kallerup. | Right: The assembled crowd at Kallerup.

Day 5 was flown at Kallerup but with a bit less wind this time but not by much. The day was pretty much uneventful and pilots continued to battle the elements, some more than others! Pierre Rondel had the misfortune to land his *Wasabi* in the sea after some disagreement with the air but luckily Per Hinrichsen who is one of the helpers is used to swimming in the sea so he went after it and got it back to dry land. Four rounds were flown and the fastest times were: 36.77, 35.11, 31.95 and 32.66 respectively.

Left: Pierre Rondel’s Wasabi in the drink. | Centre: Per Hinrichsen to the rescue. | Right: Back on dry land.

Day 6 was back at Mors so we got to close the event right where it started. A few rain showers came by during the first half of the day so Round 17 took a bit longer to finish so after starting Round 18 it was clear that it would be the last one of this competition. The wind started out around 6 m/s and then went up to about 10 m/s. The fastest times were: 49.69 and 42.30 respectively

Left: Dip Suen Sunny Tse and Angus Lee from Hong Kong. | Centre: Olav Kallhovd's Freestyler 6 from another perspective. | Right: Mark Redsell and Peter Gunning from Great Britain.

The competition was fierce with pilots moving up and down the ladder while some seemed glued to their place. From Round 6 to 15 Thorsten Folkers was in first place with Philipp Stary in second place from round 8 to 15. In Round 16 they switched places, again in Round 17 and then finally in Round 18.

Left: Mark Jensen from Australia. | Centre: Tell me it was a hard landing with out telling me!. | Right: Erlingur Erlingsson with Sverrir Gunnlaugsson Freestyler 6.

Philipp Stary from Austria is the new F3F World Championship with 15,270 points and in second place Thorsten Folkers from Germany with 15,172 points, a difference of 98 points out of 16,000 total points or 0.61%. In third place Sebastien Lanes from France with 14,616 points. In the junior category Mikkel Krogh Petersen from Denmark is in first place followed by Michał Główka in second place. It will be interesting to follow their progress over the next few years. For the first time there was a female category in the World Championship and

Katja Holstein from Germany had that honour, hopefully it's just the beginning and we'll see more female pilots over the next few years.

Selected screenshots from F3XVault. See Resources below for link to full competition results.

The *Freestyler 6* was noticeably the most popular model but there were also *Device*, *Vantage*, *Wasabi*, *Shinto*, *Respect*, *Pitbull*, *Pike Precision*, *V-JX*, *Neo*, *Grane*, *Vængur* and *Quantum* to name a few. The *V-JX* is an interesting open source project of Jochen Guenzel and Mario Perner with members of both the Austrian and German team flying it. See link to their project repository in *Resources*, below.

Left: ACD Erik Dahl Christensen and Jan Hansen CD. | Centre: Staff, helpers and judges. | Right: Long hours on the flight line.

Last but not least the organisers and staff! The organisation of the event was top notch with everything running smoothly with the staff and helpers on top of their games and obviously not their first rodeo. 972 flights in five-and-a-half days is no mean feat which they pulled off admirably in conditions from 3 to 25 m/s!

The obligatory group photo! Don't worry, you can click on it for a more detailed view (3.7MB), as you can with any picture in this report. (credit: F3F Team France)

See you all in France in 2024!

Cool New Stuff

The Sugar Glider ready to go. (credit: Sugar Glider)

We have something for every Christmas wish list — maybe even yours!

Sugar Glider

A small, easy-to-carry 1m class thermal glider.

Although it employs classic construction primarily of balsa wood, the *Sugar Glider* is designed with a modern sensibility, and the concise manual allows you to maximise the fun of assembling it.

Efficiently designed wings will win your heart in one fell swoop. It has a streamlined sweep angle, streamlined edges, a low wing load of about 8g/dm². And also it can be attached and detached from the fuselage with just one screw.

It is designed for a folding spinner that includes a motor suited for its shorter nose and body. It has flight characteristics that reduce the moment of inertia during turning flight. Depending on the pilot's preference, the stabiliser can selectively apply normal type and V-tail type. To achieve maximum stiffness while effectively minimizing the number of parts, the designers used blasa wood, carbon material and hardwoods to create an easy to assemble and robust structure.

The proportions and balance of all parts have been harmoniously arranged to achieve not only flight performance but also a visually beautiful form. The achievement of comfortable flight performance *Sugar Glider* was achieved with dozens of prototypes and over a thousand test flights during an 18 month development.

The *Sugar Glider* is small and light, so it immediately responds to small-scale heat in the atmosphere, has a small turning radius, and has a large glide ratio.

Click any image for detailed view. (credit: Sugar Glider)

To sum up, you can feel the wind better and have more opportunities to ride the thermal. It certainly gives you the happy pleasure of flying a thermal glider closer to you. You can obtain more information on Instagram: @sugarglider_f5k.

Weihnachtskarte '*Snowflake*'

Wann haben Sie das letzte Mal schöne Post erhalten?

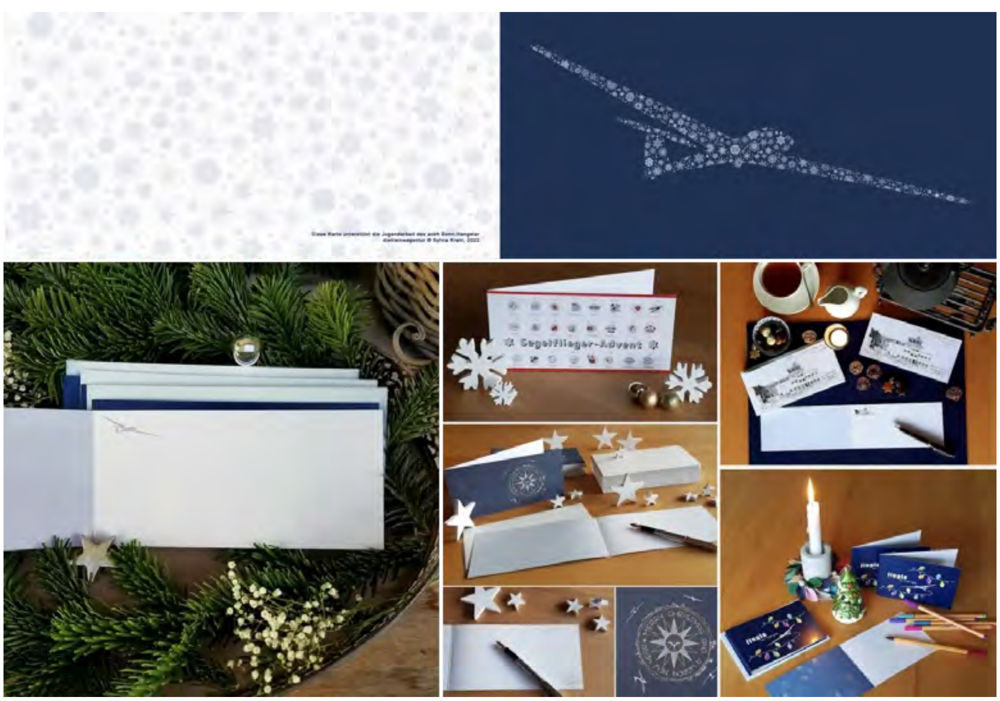
Weihnachtskarte 'Snowflake' (Bildnachweis: Sylvia Krahl)

Keine Rechnung, keine Werbung, sondern eine Karte mit ein paar persönlichen Worten? Sie wissen bestimmt noch, wie gut Sie sich dabei gefühlt haben. Da hat jemand an Sie gedacht und sich die Mühe gemacht, eine passende Karte zu kaufen und sich an den Schreibtisch zu setzen, um Ihnen mit ein paar Worten oder einem Brief gute Wünsche zu schicken. Als Dankeschön für die tolle Zeit, die Sie miteinander verbracht haben. Oder um Ihnen zu erzählen, was im letzten Jahr alles passiert ist. Vielleicht stand nur ein Gruß auf dem Papier und ein Foto war beigelegt.

Dass Sie Post dieser Art schätzen, zeigen Sie am besten, indem Sie selbst welche verschicken. Zum Beispiel mit den Weihnachtskarten unserer Jugendgruppe. Seit fünf Jahren gibt es diese schöne Tradition in unserem Verein: jedes Jahr kommt ein neues Motiv dazu, die Jugendgruppe des *Aeroclub Bonn-Hangelar e. V.* kümmert sich um die Werbung und an Weihnachten wandert der Erlös aus dem Verkauf der Karten auf das Jugendkonto. Eine kleine, aber feine Aktion, mit dessen Erlös die Jugendlichen Ausflüge, Teambuilding und Grillabende an der Feuerschale organisieren.

Mit dem Erwerb einer Karte unterstützen Sie also neben der Freude, die Sie sich und dem Empfänger Ihrer Weihnachtspost machen, auch noch die Nachwuchsförderung.

Als Dankeschön an den Fluglehrer, netter Gruß an die liebe Oma oder als schicke Hülle für einen Gutschein: mit dieser Karte machen Sie Freunden der Fliegerei eine Freude.



Klicken Sie auf das Bild für mehr Details. (Bildnachweis: Sylvia Krahl)

DIN lang, 4-seitig, mit Umschlag. 10,5 cm x 21 cm, farbig, glänzend auf 350 g Karton, mit Umschlag. Weitere Informationen zu dieser und den anderen Karten finden Sie auf dem Instagramprofil von Sylvia Krahl, die die Karten für die Jugendgruppe entwirft: @sylvia.krahl

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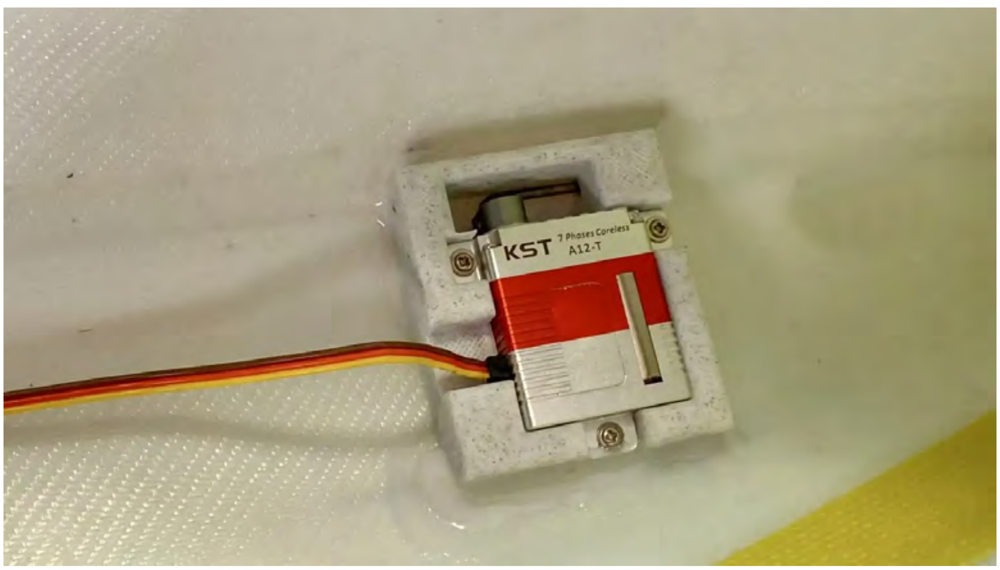
Ultra Compact Tow Release with Integrated Servo

Composite RC Gliders' new solution for this tricky, time-consuming problem.

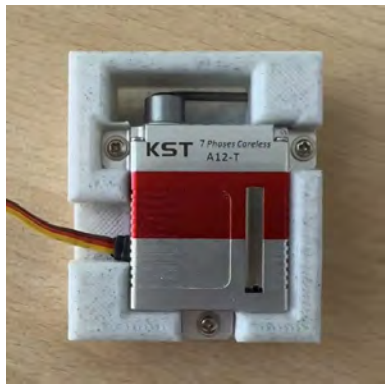


The tow release mounted in the fuselage. (credit: Composite RC Gliders)

A very compact unit suitable for gliders up to 6m wingspan or it can be used overhead in the tow plane. It's ready to mount and includes a KST A12-T Servo which is rated up to 8.4V. With the 7mm servo arm it produces amazing torque:

- 28kg force with 8.4V
- 25kg force with 7.4V
- 23kg force with 6.0V

An added benefit is that the external opening required is extremely small and perfectly flush with the surrounding surface.



Click any image for detailed view. (credit: Composite RC Gliders)

For more information see complete product details on the Composite RC Gliders website. There is also a great installation video available.

Mini Olympic II

A convenient and cost-effective redux of this classic design.

The Mini Olympic II in its natural element. (credit: Sky Bench)

The *Mini Olympic II* is the result of flyers contacting Sky Bench to ask for a half-scale version of the iconic *Olympic II* sailplane designed by Lee Renaud and kitted by Airtronics for many years. Starting around 2020, a new half-scale area of interest started in the RC sailplane hobby. Some of the interest was caused by the concern of new FAA regulations, but much of it was just the delight of making smaller, easier-to-fly, and transport versions of classic woody sailplanes.

Sky Bench were happy to oblige because they already have the copyright for the *Olympic II*. They credit Mike McCrabb and Tony Megowan who both spent time making this happen. Mike developed the original *Mini Olympic II* prototype and Tony used his CAD skills to create the kit drawing.

Click any image for detailed view. (credit: Sky Bench)

Inside the box, you will find everything you need to make the thermal version of the *Mini Olympic II* structure. Also included are the extra parts for an electric version and the parts needed for a bolt-on wing if desired. Making a 50% version is not as simple as just reducing the original plans. All stock wood sizes had to be adjusted and some areas strengthened to make for a long-lasting sailplane. Sky Bench prides itself on top-quality wood, laser cutting, written, photo-illustrated instructions, and a full-scale drawing. The specs are as follows:

- Wing span: 49.95 in
- Fuselage length: 24.5 in
- Wing Area: 203.5 in^2
- Airfoil: flat-bottom, 10% thick
- Wing loading: 5.29 oz per ft^2
- 2-channel radio required

More information on the Mini Olympic II can be obtained directly from the Sky Bench website.

Where in the World is the New RCSD?

We celebrate our readers and writers in 106 countries.

We were so pleased with our recent ‘reader/writer country count’, we have commemorated it with this colourful t-shirt available in seven great colours and a wide range of sizes. (image: Studio RCSD)

This brand new addition to our collection of quality logo merch features the flags of all 106 countries where the New RCSD is read and written — we think it looks just great, particularly when set against the light grey or white. But that’s just us — you may want something a bit jazzier. It’s a tribute to our readers all around the world and a thank you to them rolled into one. Check out the great new Where in the World is the New RCSD? t-shirt today.

Say you saw it in the New RC Soaring Digest.

Resources

- *Aeroclub Bonn-Hangelar e. V.* — “represents the interests of the air sports clubs based in North Rhine-Westphalia. It connects motor pilots, glider pilots, motor gliders, model pilots, balloonists, parachutists, ultralight pilots and hang gliders…”

The Fine Print *All product descriptions in* Cool New Stuff *are prepared in collaboration with the product’s manufacturer and/or distributor which is/are entirely responsible for ensuring the accuracy of their product’s descriptive text and images contained herein.*

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1

High-Speed Dynamic Soaring

Chis Bosley launching Spencer Lisenby's Kinetic 100 glider at Weldon Hill, California in April of 2012.

The science underpinning this fascinating flight regime.

This article originally appeared in the April, 2012 issue of the RC Soaring Digest *(see* Resources*, below). It appears here with permission of the author who also provided additional photographs prior to its republication in this issue of the* New RC Soaring Digest*. — Ed.*

Abstract

Dynamic soaring uses the gradient of wind velocity (wind shear) to gain energy for energy-neutral flight. Recently, pilots of radio-controlled gliders have exploited the wind shear associated with fast winds blowing over mountain ridges to achieve very fast speeds, reaching a record of 487 mph in January 2012.

A relatively simple two-layer model of dynamic soaring was developed to investigate factors that enable such fast speeds. The optimum period and diameter of a glider circling across a thin wind-shear layer predict maximum glider airspeed to be around 10 times the wind speed of the upper layer (assuming a maximum lift/drag of around 30). The optimum circling period can be small ~1.2 seconds in fast dynamic soaring at 500 mph, which is difficult to fly in practice and results in very large load factors ~100 times gravity. Adding ballast increases the optimum circling period toward flyable circling periods of 2–3 seconds. However, adding ballast increases stall speed and the difficulty of landing without damage. The compressibility of air and the decreasing optimum circling period with fast speeds suggest that record glider speeds will probably not increase as fast as they have during the last few years and will probably level out below a speed of 600 mph.

1. Introduction

In April, 2011, I watched pilots of radio-controlled (RC) gliders at Weldon Hill California using dynamic soaring to achieve speeds up to 450 mph in wind gust speeds of 50–70 mph. One almost needs to see and hear these fast gliders to believe their amazing performance. These observations raised questions about how gliders could fly so fast and led me to try and understand the relevant dynamics. The motivation was the possibility that the technology of these gliders and the experience of the pilots could be used to help develop a fast robotic albatross UAV (unmanned aerial vehicle) for surveillance, search and rescue, and rapid scientific sampling of the marine boundary layer and ocean surface.

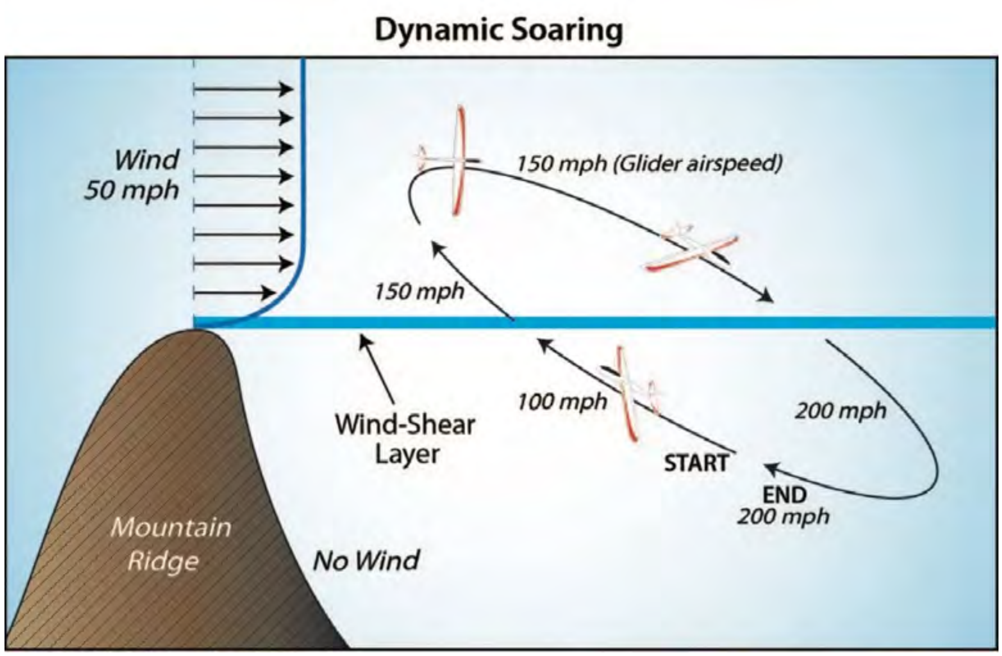


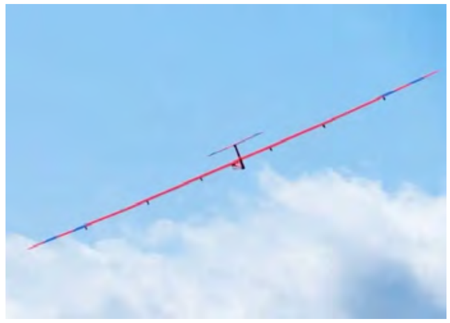
Figure 1. Idealized example of the increase of airspeed of a dragless glider soaring through a thin wind-shear layer in which the wind increases from zero below the layer to 50 mph above. This example shows how a glider could use dynamic soaring in the region downwind of a ridge crest as observed at Weldon. Starting in the lower layer with an assumed airspeed of 100 mph, a glider climbs upwind a short distance vertically across the wind-shear layer, which increases glider airspeed to 150 mph. The glider then turns and flies downwind with the same airspeed of 150 mph. During the turn, the glider's ground speed increases to 200 mph in the downwind direction and consists of the 150 mph airspeed plus (tail) wind speed of 50 mph. The glider descends downwind a short distance vertically across the wind-shear layer, which increases the glider's airspeed to 200 mph. The glider turns upwind flying with airspeed of 200 mph. Thus, one loop through the wind-shear layer increases the glider's airspeed from 100 mph to 200 mph (two times the 50 mph wind speed in the upper layer). The nearly-circular flight modeled in this paper is shown as an ellipse in this schematic figure.

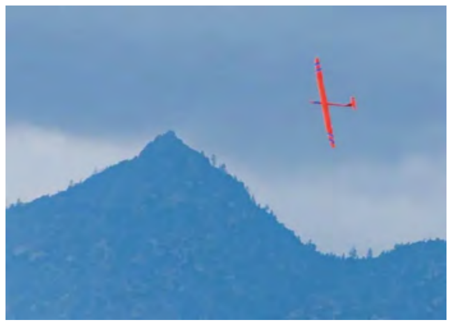
Recently, I developed a fairly simple model of dynamic soaring to help understand how albatrosses use this technique to soar long distances without flapping their wings (Richardson, 2011). This present paper uses this model but concentrates on much faster glider airspeeds, which are more than ten times the typical wandering albatross airspeed of 35 mph. Specific questions explored are: 1) what are the key parameters of the flight that allow such high speeds to be achieved, 2) how can the flight be optimized for fast speeds, 3) what are the maximum airspeeds that can be achieved with realistic winds.

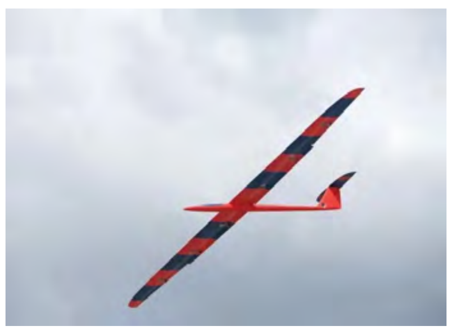
2. Observations of RC Glider Soaring

The RC dynamic soaring I observed at Weldon exploited the wind shear caused by fast wind blowing over a sharp-crested mountain ridge (see *RCSpeeds.com* linked in *Resources*, below). The RC gliders flew in approximately circular loops lying roughly along a plane that tilted upward toward the wind direction and extended above the ridge crest. From the windy region above the ridge, the gliders descended headed in a downwind direction into the low-wind region below and downwind of the ridge crest. They then turned and climbed in an upwind direction back into the fast wind in the upper layer above the ridge crest. The gliders flew in fast steeply-banked loops with a loop period of around 3 seconds. The wings looked like they were nearly perpendicular to the plane all the way around a loop, implying very large accelerations. An accelerometer on one of the gliders recorded a maximum acceleration of 90 g, the accelerometer's upper limit (Chris Bosley, personal communication). At times the gliders were perturbed by turbulent wind gusts, and the pilots needed to quickly respond in order to prevent the gliders from crashing into the side of the ridge. High-speed crashes totally destroyed five gliders that day. Glider speeds up to 300–450 mph were measured with radar guns, usually after a glider had reached its lowest point on a loop and was climbing upwind again. This suggested that the recorded speeds are representative of typical speeds in the loop and could be somewhat slower than peak speeds. Wind speed gusts of 50–70 mph were measured on the ridge crest by holding a small anemometer overhead at a height 7 feet above ground level. Anecdotally, maximum glider speeds are around 10 times the wind speed, although this seems to be more realistic at lower speeds (< 350 mph) than at higher speeds (> 350 mph) (S. Lisenby, personal communication). However, there are generally very few wind velocity measurements with which to compare the glider speeds.

The gliders had ailerons and an elevator to control flight and a fixed fin in place of a moveable rudder. Flaps were used to reduce the stall speed when landing.







Left: Spencer Lisenby's Kinetic 100 at speed. | Centre: Coming in for a landing over top of Weldon Hill. | Right: Final approach to landing zone, flaps down.

3. Inferences about the Wind Field

Wind velocity over a ridge crest generally increases with height from near zero velocity at the ground level. The largest vertical gradient of wind velocity (largest wind shear) is located in a thin boundary layer located within several feet of the ridge crest. Fast wind blowing over a sharp-crested ridge usually forms an area of weaker wind or a lee eddy just downwind of the ridge crest and below the level of the crest. Located above this region of weak wind is a thin wind-shear region, a wind-shear boundary layer that separates from the ridge crest, and above that a layer of stronger wind and reduced wind shear. The wind-shear layer is inferred to extend nearly horizontally downwind of the ridge crest and gradually thicken with distance downwind. The glider loops crossed the wind-shear layer where it was thin just downwind of the ridge crest (see Figure 1).

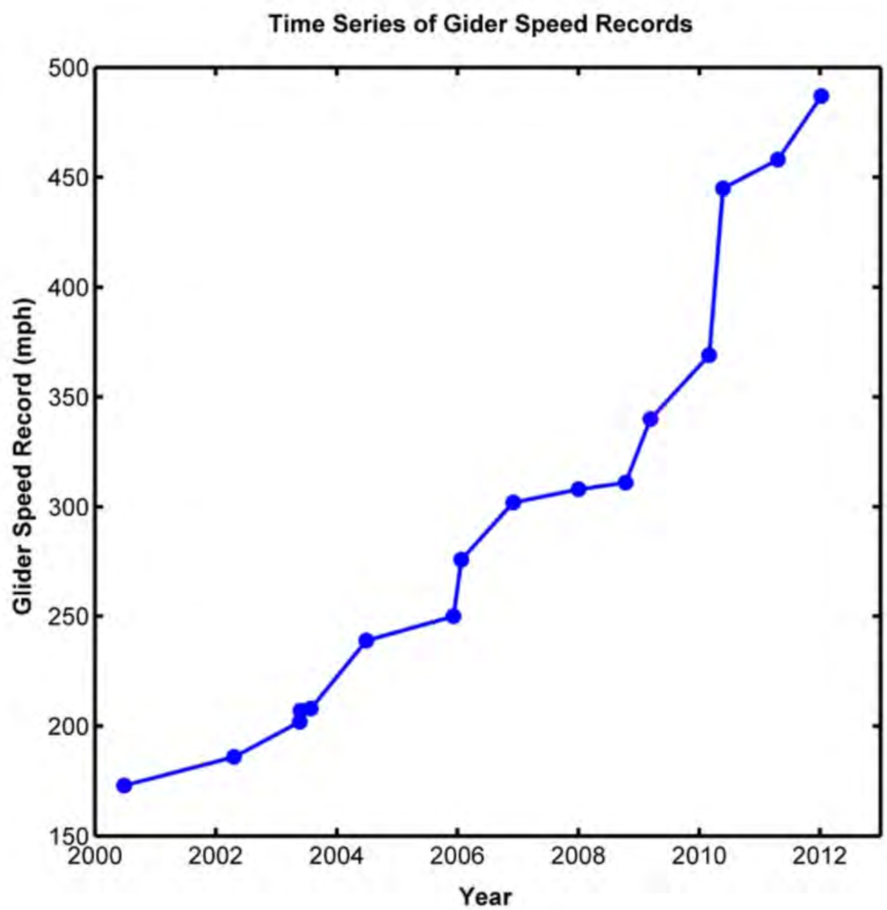


Figure 2. Time series of maximum recorded speeds of RC gliders using dynamic soaring as listed in the website RCSpeeds.com. Each value represents an unofficial world record as measured by radar gun. The charted record holder is Spencer Lisenby who flew a Kinetic 100 (100 inch wing span) glider at a speed of 487 mph in January 2012. On 06 March 2012 Spencer flew the Kinetic 100 to a new record speed of 498 mph. (See 'New World Record 498mph!!' in Resources, below)

4. Schematic Illustration of Dynamic Soaring

The technique of dynamic soaring illustrated by the glider flight is to cross the wind-shear layer by climbing headed upwind, to then turn downwind, and to descend headed downwind (Figure 1). Each crossing of the wind shear layer increases the airspeed and kinetic energy of a glider. The rate of gain of airspeed and kinetic energy can be increased by increasing the frequency of the loops. Several things tend to limit a glider's airspeed including increased drag associated with both faster airspeeds and steeply-banked turns. When the gain of energy from crossing the wind-shear layer equals the loss due to drag, a glider reaches equilibrium in energy-neutral soaring.

Temporal wind gusts, in contrast to the structure gusts encountered by crossing the wind-shear layer, can be used to gain additional energy. A faster-than-average wind-speed gust contains greater-than-average wind shear, through which a glider could extract a greater-than-average amount of energy. The trick of soaring in gusts is to maximize time in the gusts and minimize time in the lulls.

5. Brief History of Dynamic Soaring

Interest in dynamic soaring began in the late 1800's as mariners watched albatrosses soaring over the ocean without flapping their wings. Observers tried to understand and model the birds' soaring techniques in order to adapt them for human flight. Two theories were suggested to explain how an albatross could extract energy from wind. The first theory, which has gained prominence, proposed that an albatross uses wind shear, the increase in wind velocity with height above the ocean surface, to gain energy (dynamic soaring). The second theory proposed that an albatross uses updrafts over waves to gain energy (wave-slope soaring). Albatrosses probably use both techniques, depending on the local wind and waves, but dynamic soaring is thought to provide most of the energy for sustained soaring. Albatrosses appear to exploit the thin wind-shear layer located above lee eddies, which are located downwind of ocean wave crests, as described by Pennycuick (2002).

The concept of dynamic soaring was first described by Lord Rayleigh in 1883, and the phrase "dynamic soaring" was used as early as 1908 by F. W. Lanchester. Over the years dynamic soaring has been discussed and modeled by many people, although only quite recently were the aerodynamics correctly developed (see Lissaman, 2005;

Sachs, 2005). A problem for non-aerodynamicists is that the aerodynamic differential equations describing the accelerated twisting, turning, swooping flight of gliders in wind shear are very complex, which makes it difficult to understand the relevant dynamics. This note is an attempt to try to express the physics of dynamic soaring in a simpler framework and apply it to fast glider flight.

A little over a decade ago, pilots of RC gliders began using dynamic soaring and have been exploiting it to fly gliders downwind of mountain ridges much faster than had been previously possible. During the last 12 years, dynamic soaring speeds increased remarkably from around 170 mph in year 2000 up to 487 mph in 2012 with no sign of leveling off (Figure 2).

Speed gains have been achieved with the development of high performance airfoils, stronger airframes, better servos, and increased pilot experience. Along with these developments, pilots have flown gliders in progressively faster winds and larger wind shears. Along the way were many structural failures due to the large accelerations associated with fast highly-banked loops. Numerous crashes were caused by trying to fly fast gliders close to the ground near ridge crests. Maintaining control of gliders in quick loops and in wind turbulence is challenging and requires fast and accurate reflexes. In addition, large stall speeds of high-performance gliders make them tricky to fly at slow speeds and to safely land on top of a mountain ridge.

6. Model of Dynamic Soaring

The approach here uses the characteristics of observed glider loops to develop a simple model of dynamic soaring based on Rayleigh's (1883) concept of soaring across a sharp wind-shear layer and on the flight dynamic equations of motion (Lissaman, 2005). The modeled flight pattern is referred to as the Rayleigh cycle because he was first to describe the concept of dynamic soaring. The model provides a relatively easy way to understand the essential physics of dynamic soaring and provides predictions of soaring airspeeds, which agree well with more complex simulations of albatross flight (Lissaman, 2005; Sachs, 2005, Richardson, 2011). The Rayleigh cycle, which uses two horizontal homogenous wind layers, is the most efficient way for a glider in nearly-circular flight to gain energy from a wind profile and thus indicates the maximum amount of airspeed that can be achieved using dynamic soaring in energy-neutral flight.

When a glider soars in wind, the glider's airspeed (speed through the air) is different from its ground speed (speed relative to the ground). This should be kept in mind because airspeed, and not ground speed, is the quantity most relevant to flight. Aerodynamic forces on a glider depend on its airspeed not ground speed. Sufficient airspeed must be maintained to avoid a stall, which could be fatal at low altitude. The analysis of airspeed and ground speed leads to different conclusions about where kinetic energy is gained in dynamic soaring. An increase of glider airspeed comes from crossing the wind-shear layer. Most increase of ground speed occurs as a glider turns from a direction headed upwind to a direction downwind; during the turn wind does work on the glider and accelerates it in a downwind direction. Radar measurements of glider speed are relative to the ground and can be significantly different from glider airspeed.

Over time, gravity and drag relentlessly force a glider downward through the air. In balanced flight the glider's sinking speed through the air represents the glider's rate of energy loss. In order to continuously soar, a glider must extract sufficient energy from the atmosphere to counter the loss due to drag. For many years gliders exploited updrafts along ridges to gain energy from the wind and continuously soar, but recently gliders have used the vertical gradient of horizontal winds to gain energy; the exceptionally fast speeds achieved using wind gradients suggest that dynamic soaring is an effective way to gain energy.

The Rayleigh cycle of dynamic soaring as shown in Figure 1 was used to model a glider soaring in nearly-circular loops along a plane tilted upward into the wind similar to the glider observations at Weldon. The essential assumptions are that 1) the plane crosses the wind-shear layer at a small angle with respect to the horizon so that vertical motions can be ignored, 2) the average airspeed and average glide ratio can be used to represent flight in the circle, and most importantly, 3) conservation of energy in each layer requires a balance between the sudden increase of airspeed (kinetic energy) caused by crossing the shear layer and the gradual loss of airspeed due to drag over half a loop, resulting in energy-neutral flight. The motion during each half loop is somewhat similar to a landing flare when a glider maintains constant altitude and airspeed is slowly dissipated by drag. This study assumes that the lower layer has zero wind speed and that the increase of wind speed across the wind-shear layer is equal to the wind speed in the upper layer.

V (mph)	200		300		400		500		600	
V_c (mph)	45	55	45	55	45	55	45	55	45	55
t_{opt} (sec)	2.9	4.3	1.9	2.9	1.5	2.2	1.2	1.7	1.0	1.4
d_{opt} (feet)	270	400	270	400	270	400	270	400	270	400
W_{min} (mph)	20		30		40		50		60	
Bank angle (deg)	87.1	85.7	88.7	88.1	89.3	88.9	89.5	89.3	89.7	89.5
Load factor	20	13	44	30	79	53	123	83	178	119

Table 1. Optimum loop period (topt) and diameter (dopt) and the minimum wind speed (Wmin) required for different glider airspeeds in energy-neutral dynamic soaring. V is the average airspeed (speed through the air) of a glider circling in a Rayleigh cycle. Vc is the assumed cruise airspeed (45 mph) of the glider corresponding to the airspeed of maximum lift/drag, which was assumed to equal 31.4 in this example. Cruise airspeed increases to 55 mph by adding ballast of around 50% of the original glider weight. The optimum loop period topt corresponds to the minimum wind speed Wmin in the upper layer required for dynamic soaring at the listed glider airspeeds (Eq. 6). Optimum loop diameter dopt corresponds to the optimum loop period (Eq. 9). Bank angle is for balanced circular flight. Load factor is equal to 1/cosφ and is the total acceleration of the glider, including gravity plus centripetal acceleration, normalized by gravity.

V (mph)	500					600	
t (sec)	1.0	1.5	2.0	2.5	3.0	2.0	3.0
d (feet)	230	350	470	580	700	560	840
W_{min} (mph)	51 (58)	52 (51)	58 (53)	66 (53)	78 (58)	77 (63)	103 (77)
V/W_{min}	9.9 (8.7)	9.6 (9.9)	8.7 (9.9)	7.6 (9.4)	6.7 (8.6)	7.8 (9.5)	5.8 (7.8)
Bank angle (deg)	89.6	89.4	89.2	89.0	88.0	89.3	89.0
Load factor	143	95	72	57	48	86	57

Table 2. Minimum wind speed (Wmin) required to fly at 500 mph (and 600 mph) using different loop periods (t) and the associated loop diameters (d) in energy-neutral dynamic soaring. The maximum L/D is assumed to equal 31.4 at a cruise airspeed Vc of 45 mph (no ballast). V is the average airspeed of a glider circling in a Rayleigh cycle, t is an assumed loop period, and d is the corresponding loop diameter. Wmin is the minimum wind speed in the upper layer required for dynamic soaring at the listed glider airspeed. Values in parentheses are for a cruise airspeed Vc of 55 mph (added ballast). V/Wmin is the ratio of glider airspeed to wind speed and, when multiplied by the wind speed, indicates the maximum airspeed. Values in parentheses are for a cruise speed of 55 mph (added ballast). Bank angle is for balanced circular flight. Load factor is equal to 1/cosφ and represents the total acceleration acting on the glider, normalized by gravity.

The glide polar for a particular glider is given by values of the glide ratio **V**/**V***z*, where **V** is the glider airspeed and **V***z* is the glider's sinking speed through the air. The glide ratio is closely equal to lift/drag (**L**/**D**) for **L**/**D** values >> 1 typical of glider flight. Values of **V**/**V***z* for circular flight were modeled using a quadratic drag law, in which the drag coefficient is proportional to the lift coefficient squared, and the aerodynamic equations of motion for balanced circular flight (Lissaman, 2005; Torenbeek and Wittenberg, 2009). The equation for a glide polar can be specified by using a glider's maximum **L**/**D** value and the associated cruise speed **V**c. In balanced circular flight the horizontal component of lift balances the centripetal acceleration and the vertical component of lift balances gravity. A more complete discussion of glide polar model and derivation of relevant equations are given in the appendix. Equation numbers below refer to the equations derived in the appendix.

For a given wind speed in the upper layer, the maximum possible glider airspeed coincides with an optimum loop period (t*opt*) and the associated optimum loop diameter (d*opt*). For fast glider speeds, > 150 mph, t*opt* is given by

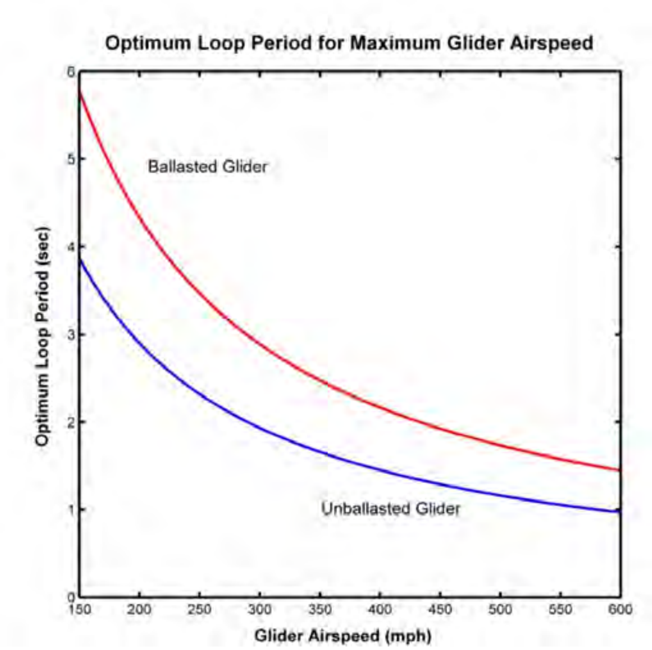
$$t_{\text{opt}} = \frac{2\pi V_c^2}{gV}. \qquad (6)$$

V*c* is the glider cruise speed, **V** is the glider airspeed, and g is gravity. Equation 6 indicates that t*opt* is inversely proportional to glider airspeed. The optimum loop period decreases with increasing glider airspeed because drag increases with airspeed, which requires more frequent shear-layer crossings to achieve a balance and energy-neutral flight.

The optimum loop diameter d*opt* is given by

$$d_{opt} = 2V_c^2/g. \qquad (9)$$

Equation 9 reveals that the optimum loop diameter is independent of glider airspeed but is proportional to cruise airspeed squared.



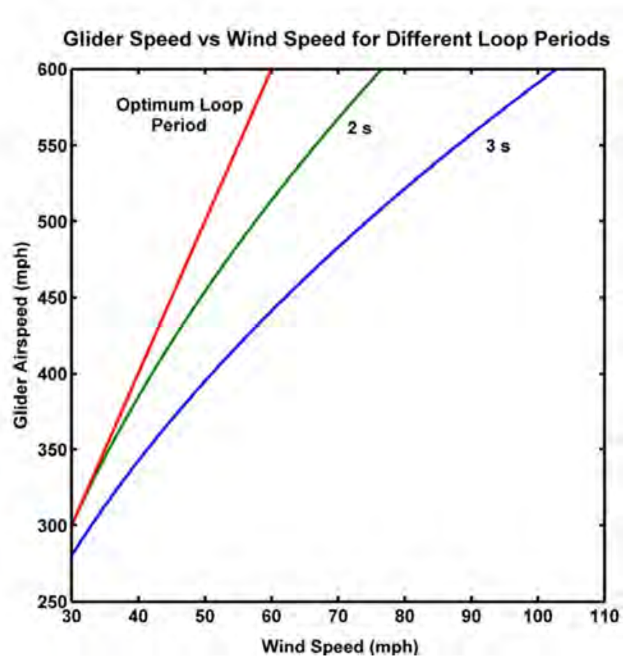


Figure 3 (left). Optimum loop period topt required to achieve the maximum glider airspeed in a Rayleigh cycle plotted as a function of glider airspeed. Curves are shown for the unballasted (Vc = 45 mph) and ballasted (Vc = 55 mph) gliders. Ballast is around 50% of the unballasted glider weight. | Figure 4 (right). Maximum glider airspeed as a function of wind speed using a Rayleigh cycle and the unballasted glider (Vc = 45 mph). Curves are shown for the (variable) optimum loop period (see Figure 3) as well as for constant loop periods of 2 s and 3 s.

Equation 8 indicates that for fast flight (> 150 mph) the maximum average airspeed in a Rayleigh cycle is proportional to the wind speed **W** in the upper layer. For a high-performance RC glider like the *Kinetic 100*, $(V/V_z)_{max}$ is around 30 (S. Lisenby, personal communication), and the maximum possible (average) dynamic soaring airspeed is around 10 times the wind speed of the upper layer. Consider a glider with a maximum **L/D** of around 30 soaring with an optimum loop period and with an upper-layer wind speed of 50 mph.

$$V_{max} = \frac{(V/V_z)_{max}}{\pi}(W). \tag{8}$$

Equation 8 predicts that the maximum possible average glider airspeed would be around 500 mph (10 times the 50 mph wind speed). A glider flying in a loop would increase its airspeed by 50 mph on crossing the wind-shear layer from 475 mph just before the crossing to 525 mph just afterward. Between shear-layer crossings airspeed would gradually decrease back to 475 mph due to drag. At these fast speeds the variation of airspeed due to vertical motions in a loop is much smaller than that due to crossing the shear layer.

The total acceleration of a glider includes centripetal acceleration and gravity and is given by the load factor, which equals $1/\cos\varphi$, where φ is the bank angle (Eq. 3). For fast dynamic soaring, the load factor is approximately equal to $2\pi V/gt$.

7. Results

The main results are the derivation of equations for the optimum loop period (Eq. 6), the optimum diameter (Eq. 9), and the maximum glider airspeed V_{max} (Eq. 8), which predicts that maximum glider speed equals around 10 times the wind speed for fast flight and $(L/D)_{max}$ around 30. It is helpful to explore these results by using values for a typical glider, so the values of the flight characteristics of a glider dynamic soaring at different airspeeds were calculated. The examples assume a high-performance glider $(L/D)_{max}$ value of 31.4 at a cruise speed V_c of 45 mph, similar to a *Kinetic 100*, the present world speed record holder (see *DSKinetic.com* in *Resources*, below). The 31.4 $(L/D)_{max}$ value was chosen so that V_{max} = 10.0 W. Adding ballast was assumed to maintain the same $(L/D)_{max}$ and to increase cruise speed V_c to 55 mph. V_c is proportional to the square root of glider weight, and (approximately) a 50% increase of glider weight increases V_c from 45 mph to 55 mph.

Figure 3 shows that, as glider speeds increase from 150 mph to 600 mph, the optimum loop period t_{opt} for the unballasted (V_c = 45 mph) glider decreases from 3.8 s to 1.0 s (t_{opt} is inversely proportional to V). Over this speed range the optimum loop diameter is 270 feet (Table 1). Small loop periods of around 2 s, or smaller, are difficult to fly in efficient dynamic soaring and stressful for the glider. More typical flyable minimum loop periods are between 2–3 s with 3 s being easier to fly and more common than 2 s, which is rare (Spencer Lisenby and Chris Bosley, personal communications). Thus, to fly at 500 mph, say, it is necessary to use flyable loop periods ~ 2–3 s, which are larger than the optimum loop period of 1.2 s and correspond to larger loop diameters of 470–700 feet (Table 2). The downside of these flyable loop periods is that the minimum wind speed required for a glider to reach an airspeed of 500 mph increases over the minimum wind speed required at the optimum period and diameter (as predicted by Eq. 7) (Figure 4). For example, the minimum wind speed $\mathbf{W}_{min}$ required for dynamic soaring at 500 mph (Eq. 4) increases from 50 mph for a 1.2 s loop (at $\mathbf{t}_{opt}$) (Table 1) up to 78 mph for a 3 s loop (Table 2).

Therefore, a major difficulty in trying to fly at glider airspeeds of 500 mph (or faster) is that by using flyable loop periods of 2–3 s the minimum required wind speed increases substantially over that at the optimum loop period and diameter (Figure 4). In other words, the glider's maximum airspeed for a wind speed of 50 mph (say) decreases from values predicted by $\mathbf{V}_{max} = 10\ \mathbf{W}$ (Eq. 8), which is based on the optimum period. In order to take advantage of $\mathbf{V}_{max} = 10\ \mathbf{W}$ one needs to fly close to the optimum period, and this becomes increasingly difficult at fast airspeeds of 500 mph (Table 1). This suggests that it will be difficult to continue to achieve such fast speed gains as seen in the last few years.

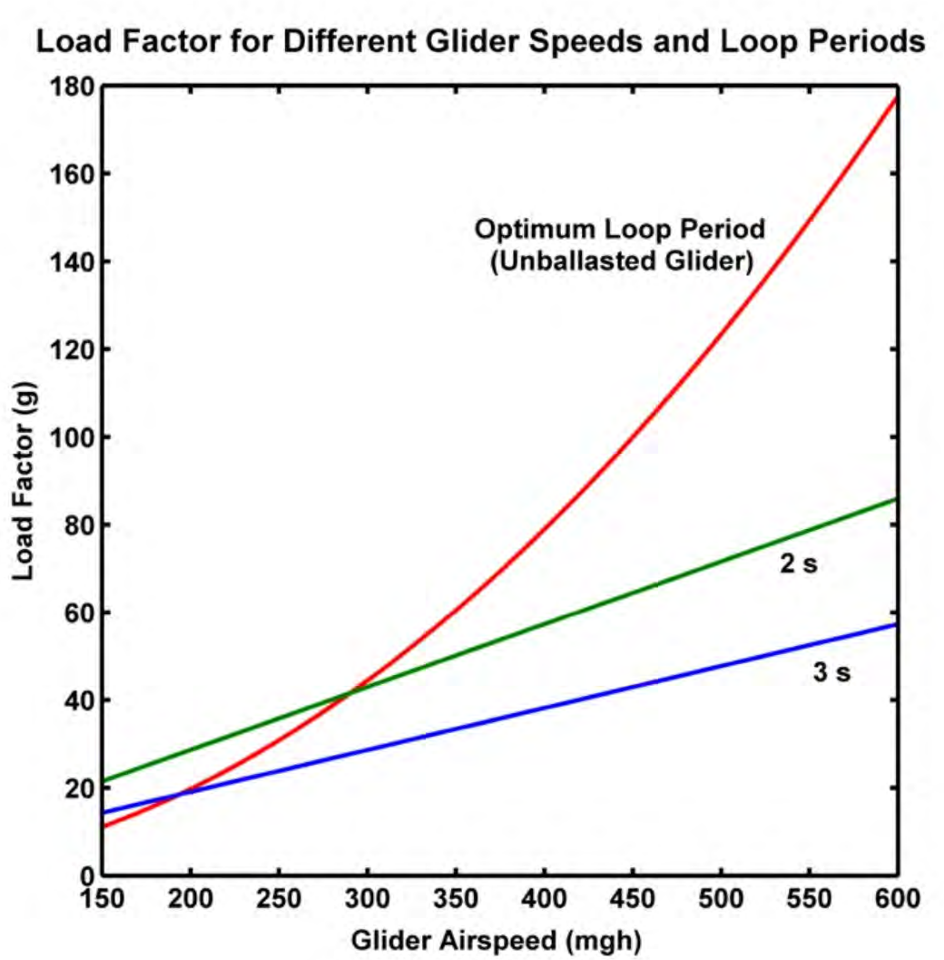


Figure 5. Load factor plotted as a function of glider airspeed and different loop periods for the unballasted glider (Vc = 45 mph). Load factor is equal to the total acceleration of the glider in terms of the acceleration of gravity (g).

The effects of flying with and without added ballast are shown in Tables 1 and 2 and Figure 3. At a glider airspeed of 500 mph, adding ballast increases the optimum loop period from 1.2 s to 1.7 s (optimum loop period is proportional to glider weight), which is still difficult to fly but closer to flyable loop periods. A benefit is that at a flyable loop period of 3 s the minimum required wind speed decreases to 58 mph (ballasted glider) from 78 mph (unballasted glider) (Table 2). A main benefit of adding ballast is to increase the optimum loop period and to reduce the minimum wind speed required to fly at 500 mph from that obtained without ballast, assuming a flyable 3 s loop period. Table 1 and Figure 3 show that the optimum loop period of the ballasted glider falls below 3 s near an airspeed of 300 mph, indicating that at airspeeds greater than 300 mph V_{max} will be below values predicted by Eq. 8. This is in accord with the anecdotal evidence of **V***max* = 10 **W** being more realistic at glider speeds below 350 mph.

Another way to interpret the effect of ballast is to compare maximum glider airspeeds achievable with a wind speed of 50 mph (say). At the optimum loop period (1.2 s) and optimum diameter (270 feet) an unballasted glider could reach 500 mph (Table 1). With a loop period of 3 s, maximum airspeed of the unballasted glider would be 370 mph (loop diameter 520 feet) and that of the ballasted glider 450 mph (loop diameter 630 feet) (Eq. 4). Thus, adding ballast increases the maximum glider airspeed over that possible without ballast (for **t** = 3 s and wind speeds > 30 mph).

Figure 5 shows the load factor (total acceleration) of an unballasted glider at airspeeds of 150 mph to 600 mph. At a glider airspeed of 500 mph and optimum loop period of 1.2 s, the load factor is 123 **g**. Increasing the loop period to 2 s at 500 mph reduces the load factor to 72 g, and increasing the loop period to 3 s reduces the load factor to 48 **g**. Table 1 also shows that the ballasted glider has a smaller load factor ~ 83 **g** than the unballasted glider ~ 123 **g** due to the larger optimum loop periods of the ballasted glider. (Load factors are similar for ballasted and unballasted gliders when using the same constant loop period). Therefore, adding ballast and increasing **V***c* from 45 mph to 55 mph reduces the load factor, and that seems beneficial. However, for a given glider airspeed, the lift force on a glider's wings is the same for both the unballasted and ballasted glider. This is because lift force equals the glider weight times the load factor, and the glider weight is larger with ballast.

Values of load factor in the tables are for average airspeeds in a loop. When a glider crosses the wind-shear layer, the airspeed suddenly increases ~ 5% over the average airspeed and that can cause a ~ 10% jump in load factor and lift force over average values given in the tables.

8. Speed Limits for Dynamic Soaring

At a critical aircraft speed of (roughly) Mach 0.7 ~ 540 mph (or greater) the flow of air past the aircraft can increase locally and reach, in places, the speed of sound, Mach 1 ~ 770 mph (see Torenbeek and Wittenberg, 2009). The aircraft speed at which this occurs depends on the wing shape, the angle of attack, and the particular configuration of the aircraft. Some modifications that have led to a higher critical speed are a supercritical airfoil, swept wings, and a smooth variation from nose to tail of an aircraft's cross-sectional area and a small maximum area (area rule). At the critical speed, shock waves begin to form due to the compressibility of air, and the aerodynamics of incompressible flow is no longer valid. The lift coefficient drops, drag coefficient increases, and lift/drag decreases enormously. The linear relationship **V***max* = 10 **W** fails, since maximum lift/drag (Eq. 8) decreases, even when flying at the optimum loop period and diameter for incompressible flow. This suggests that an increasingly large wind speed would be required to obtain a particular glider airspeed, larger than predicted by **V***max* = 10 **W**.

At an airspeed of 600 mph, the optimum loop period of the Rayleigh cycle is 1.0 s for the unballasted glider and 1.4 s for the ballasted glider, and the wind speeds required to fly with loop periods of 2–3 s increase substantially over 60 mph (Table 1). The minimum required wind speed of an unballasted glider is 103 mph for a loop period of **t** = 3 s (Table 2). Adding ballast decreases the minimum required wind speed to 77 mph for **t** = 3 s (Figure 3). Thus, adding ballast could help gliders reach 600 mph, assuming that loops could be flown with periods of 2–3 s and that wind speeds of 77 mph are available and flyable. Of course, reaching 600 mph using these wind speeds is based on a glider flying a nearly-circular loop in a two-layer Rayleigh cycle, which gives the maximum amount of energy possible from wind shear. In practice, somewhat less energy would be gained than from a Rayleigh cycle, and thus a larger wind speed would be needed to achieve the airspeeds predicted using the Rayleigh cycle. For example, flying a nearly-circular loop through a linear wind shear would result in around 50% of the maximum glider airspeed achievable in the two-layer case, assuming a similar increase of wind velocity over the heights flown. Additional limits to speed are the structural strength of the glider, which is subjected to very large accelerations and lift forces, and the glider's ability to control flutter at high speeds.

In summary, although record glider speeds have increased rapidly during the last few years up to 487 mph (Figure 2), and the shape of the curve in Figure 2 looks like it could continue upwards to much higher glider speeds, the limits mentioned above — the decreasing optimum loop period at higher speeds, the effects of the compressibility of air, and the larger wind speeds required to reach a particular glider airspeed — suggest that maximum speeds in dynamic soaring will tend to level out near between 500 and 600 mph. Further modifications of gliders for high-speed flight might help increase maximum speeds somewhat, but these modifications would probably make it difficult to fly at slower speeds and land safely. The addition of an autopilot might possibly help to fly a glider at small loop periods.

9. Conclusions about How to Soar at 500 MPH

The following conclusions about how to soar at 500 mph were derived from the analysis of the Rayleigh cycle model of dynamic soaring:

1. Fly a high-performance and strong glider with a large maximum **L**/**D** and large associated cruise airspeed (**V***c*). A larger maximum **L**/**D** results in a larger glider airspeed for a given wind speed (Eq. 8). A larger cruise speed results in a larger optimum loop period (**t***opt*), closer to flyable airspeeds of 2–3 s (Eq. 6).
2. Fly in fast wind ~ 50–70 mph (or more) and large wind shear (Table 2).

3. Fly as close to the optimum loop period (Eq. 6) and optimum loop diameter (Eq. 9) as possible because that increases the maximum glider airspeed to be around 10 times the wind speed ($\mathbf{V}_{max}$ = 10 **W**) and results in the fastest airspeed for a given wind speed (Eq. 8). However, fast flight at optimum loop periods results in large accelerations and large lift forces and requires very strong gliders. Flyable loop periods (~ 2–3 s) are significantly larger than the optimum loop period ~ 1.2 s of an unballasted glider at 500 mph and increase the minimum required wind speed to reach 500 mph (Table 1).
4. Add ballast to increase the cruise airspeed $\mathbf{V}_c$ because that increases the optimum loop period toward flyable loop periods and tends to reduce the minimum wind speed and shear required for flight at 500 mph (Tables 1 and 2). However, increasing $\mathbf{V}_c$ leads to higher stall speeds and difficulties in safely landing a glider on a ridge crest. For this reason, S. Lisenby, (personal communication) limits ballast to around 25% of the weight of his unballasted *Kinetic 100* glider.
5. Fly at high altitudes and warm temperatures where air density is lower, which has effects similar to adding ballast. Warm temperatures tend to keep the critical airspeed high.

To further investigate the dynamic soaring of gliders, it would be helpful to add instruments to measure at high resolution, positions, orientations, velocities and accelerations over the ground and through the air, as well as information about the structure of the wind interacting with ridges. It
would be useful to continuously monitor glider airspeeds and groundspeeds in order to more accurately document maximum airspeeds. With this information one might be able to refine glider performance and achieve faster airspeeds. Numerical modeling could be used to further investigate high-speed dynamic soaring in more realistic conditions (wind interacting with a ridge) and help refine high-performance glider design.

Acknowledgements

Chris Bosley and Spencer Lisenby helped with my visit to Weldon to see fast dynamic soaring and explained and discussed glider dynamic soaring techniques. Don Herzog flew us down to Bakersfield in his “high-performance” Trinidad airplane at 200 mph (much slower than the RC gliders) and joined in the trip up to Weldon. Paul Oberlander drafted Figure 2. Steve Morris and Pritam Sukumar read an earlier version of this paper and provided helpful comments about how to improve it.

Left, Centre: Spencer Lisenby assembling his Kinetic 100 and preparing for launch at Weldon Hill, California. | Right: Spencer flying a fast (~ 450 mph) dynamic soaring loop.

Appendix — Modeled Rayleigh Cycle

In the modeled Rayleigh cycle the loss of potential energy over a half loop (**t**/2) is given by **mg**(**t**/2)**V***z*, where **m** is mass, **g** is gravity, **t** is the period of a loop, and **V***z* is the glider's sinking speed through the air due to drag. Conservation of energy for energy-neutral soaring requires that this energy loss must be balanced by the sudden gain in kinetic energy (airspeed) from crossing the wind-shear layer, which is given by $m(V_2^2 - V_1^2)/2$, where V_1 is the airspeed before crossing the wind-shear layer, and V_2 is the airspeed after crossing the layer. In this latter term, $V_2^2 - V_1^2 = (V_2 - V_1)(V_2 + V_1)$. $V_2 + V_1$ is assumed to equal twice the average airspeed (2**V**) in the nearly-circular flight, and $V_2 - V_1$ is the increase of airspeed **ΔV** of a glider crossing the wind- shear layer, which is assumed to equal the vertical increase of wind speed (**ΔW**) across the layer and also the wind speed **W** of the upper layer, assuming zero wind speed in the lower layer. Conservation of energy and the approximations given above indicate that

$$\Delta V = \frac{gt}{2(V/V_z)}, \tag{1}$$

where **V**/**V***z* is the glide ratio averaged over a half loop and over **ΔV**. Values of **V**/**V***z* define the glide polar for a particular glider and indicate values of its sinking speed **V***z* through the air as a function of airspeed *V*. The glide ratio is closely equal to lift/drag (**L**/**D**) for **L**/**D** values >> 1 typical of glider flight. Lift $L = C_l(\rho/2)V^2S$, drag $D = C_d(\rho/2)V^2S$, C_l is the lift coefficient, C_d the drag coefficient, **ρ** the density of air, and **S** the characteristic area of the wings.

The decrease in airspeed at the assumed nearly-constant height during a half loop was obtained by balancing the rate of change of airspeed (kinetic energy) with dissipation due to drag. This balance indicates that $dV/dt = g/(V/V_z)$. Since V/V_z is nearly constant in the relevant glider airspeed range **ΔV** centered on a particular average airspeed, airspeed decreases nearly linearly in time. (The variation of V/V_z is around 10% of the average V/V_z in an energy-neutral loop.) Therefore, the total decrease of airspeed **ΔV** in a half loop (**t**/2) is equal to $gt/2(V/V_z)$ as derived above (Eq. 1).

Values of V/V_z for circular flight were modeled using a quadratic drag law, in which the drag coefficient is proportional to the lift coefficient squared, and the aerodynamic equations of motion for balanced circular flight (Lissaman, 2005; Torenbeek and Wittenberg, 2009). In balanced circular flight the horizontal component of lift balances the centripetal acceleration and the vertical component of lift balances gravity. Specifically, V/V_z was modeled by

$$V/V_z = \frac{2(V/V_z)_{\max}}{(V/V_c)^2 + (V_c/V\cos\varphi)^2}, \qquad (2)$$

where $(V/V_z)_{max}$ is the maximum glide ratio at V_c the associated cruise airspeed (airspeed of minimum drag) of a representative glider in straight flight, **φ** is the bank angle, and cos**φ** is given by

$$\cos\varphi = \sqrt{\frac{1}{(2\pi V/gt)^2 + 1}}. \qquad (3)$$

Combining Equations (2) and (3) with (1) indicates that

$$\Delta V = \frac{gt}{4(V/V_z)_{\max}}\left[(V/V_c)^2 + (V_c/V)^2 + (2\pi V_c/gt)^2\right]. \qquad (4)$$

The $(2\pi V/gt)^2$ term is due to the centripetal acceleration and bank angle. Equation 4 indicates that for a particular glider in energy-neutral soaring, the glider airspeed (**ΔV**) gained by crossing the wind-shear layer (and the gradual loss in a half loop) is a function of both the loop period *t* and the average airspeed **V**.

A minimum **ΔV** (and also minimum **ΔW** and minimum **W**) for a given glider airspeed occurs at an “optimum” loop period t_{opt} coinciding with minimum energy loss in a loop (minimum $V_z t$). The optimum loop period (t_{opt}) was obtained by setting the derivative **d(ΔV)/dt** of (Eq. 4) equal to zero and solving for **t**.

$$t_{opt} = \frac{2\pi V_c/g}{\sqrt{(V/V_c)^2 + (V_c/V)^2}}. \tag{5}$$

At fast glider speeds >150 mph and for **V***c* ~ 50 mph, $(V/V_c)^2 >> (V_c/V)^2$ and $(V_c/V)^2$ can be neglected. This simplifies Eq. 5 to

$$t_{opt} = \frac{2\pi V_c^2}{gV}. \tag{6}$$

Equation 6 indicates that t_{opt} decreases with increasingly large **V**. Substituting Eq. 6 into Eq. 4 provides an expression for minimum **ΔV** (and minimum **ΔW** and minimum **W**) for a given **V**. The minimum wind speed W_{min} needed for a given glider airspeed **V** in energy neutral dynamic soaring is

$$W_{min} = \frac{\pi V}{(V/V_z)_{max}}. \tag{7}$$

This equation can be rearranged to provide the maximum glider airspeed V_{max} for a given wind speed **W**

$$V_{max} = \frac{(V/V_z)_{max}}{\pi}(W). \tag{8}$$

Equation 8 indicates that for fast flight (> 150 mph) the maximum average airspeed in a Rayleigh cycle is proportional to wind speed. It is important to note that this linear relation depends on flying with an optimum loop period. Other loop periods result in a smaller maximum airspeed for a given wind speed.

The diameter of a loop is given by $d = Vt/\pi$. Substituting into this equation the expression for optimum loop period t_{opt} in fast flight (Eq. 6) gives the optimum loop diameter d_{opt}

$$d_{opt} = 2V_c^2/g. \quad (9)$$

Equation 9 reveals that the optimum loop diameter is proportional to cruise airspeed but is independent of glider airspeed.

The total acceleration of a glider includes centripetal acceleration and gravity and is given by the load factor, which equals **1/cosφ** (see Eq. 3). For fast dynamic soaring (**2πV/gt**)² >> 1, and the load factor is approximately equal to **2πV/gt**.

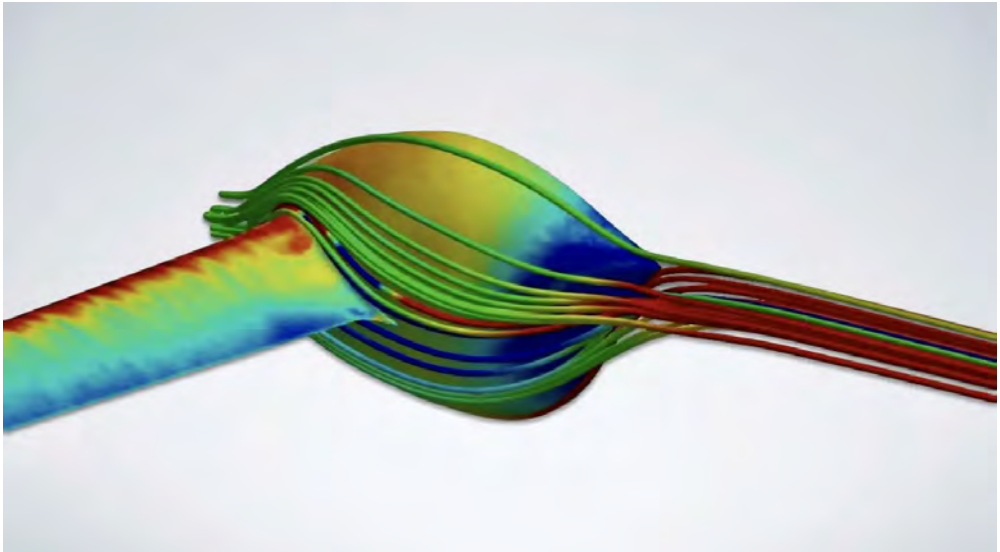
Resources

- *Dr. Philip L. Richardson* Senior Scientist Emeritus, Physical Oceanography Department, Woods Hole Oceanographic Institution. Research interests include the "dynamic soaring of albatrosses and autonomous unmanned aerial vehicles; the general ocean circulation and its low-frequency variability; Gulf Stream, Equatorial Currents, Agulhas-Benguela Current system, Deep-Western Boundary Currents, Ocean eddies and current rings; historical aspects of oceanography."
- *High Speed Dynamic Soaring* by Philip L. Richardson — This is the original article exactly as it appeared in the April, 2012 issue of the *RC Soaring Digest*.
- *RCSpeeds.com* From the website — "Welcome to *RCSpeeds.com*, the site designed to serve pilots who strive to fly radio control models fast. RCSpeeds will recognize your achievements in Dynamic Soaring. World speed records, dates, planes and locations can be posted for any pilot…"
- *DSKinetic.com* From the website — "While most commercially available DS planes are simply strengthened versions of non-DS airframes, the Kinetic family of sailplanes was designed specifically for High Speed Dynamic Soaring…"

- *New World Record 498mph!!* — Discussion thread on RCGroups which is roughly contemporaneous with the original publication of this article in April of 2012. It appears here to help provide a complete record of developments, and the timely discussion thereof. See immediately below for the current record which we had the good fortune of covering in the very first issue of the *New RCSD*.
- *Spencer Lisenby Clocks Record-Breaking 882 km/h at Parker Mountain* from the January, 2021 issue of the *New RC Soaring Digest*. — "In a remarkable advancement of the state-of-the-art Spencer Lisenby…has broken the outright speed record for a model aircraft. On January 19th, 2021 Lisenby's Kinetic Transonic DP hit 882 km/h (548 mph) at the famed Parker Mountain location…"

All images by the author unless otherwise noted. Thanks to Editorial Assistant Michelle Klement for her invaluable assistance in preparing this article for publication in the New RCSD*.* *Read the next article in this issue, return to the previous article in this issue or go to the table of contents. A PDF version of this article, or the entire issue, is available upon request.*

Dream 2700 | A Tailless Tale

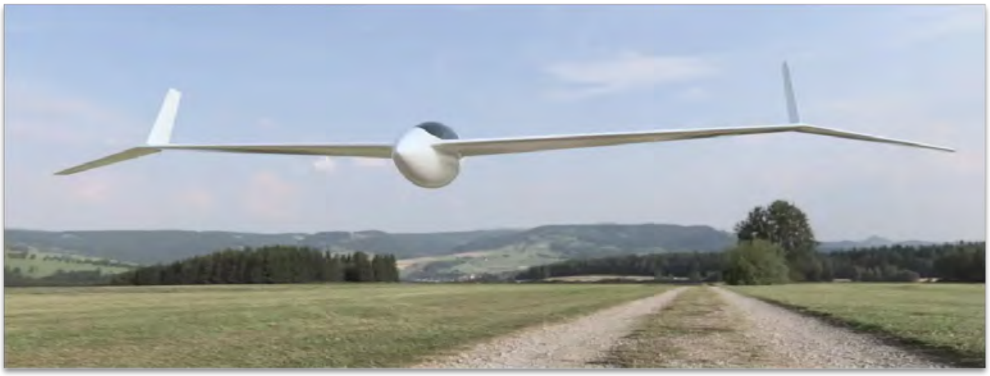


The Dream 2700 in the CFD ‘wind tunnel’.

Part II: Design Optimization and the Bell-Shaped Lift Distribution

Those who have not yet done so may want to read the first part of this series, then continue with this article — Ed.

In this second part of the journey, I will guide you through the main aerodynamic design challenges of a tailless sailplane. Nowadays, several calculation tools are available to the hobbyist and — with some effort — it is possible to run a preliminary validation of a concept, minimizing the risk of a maiden flight crash. Computational Fluid Dynamics (CFD) tools are today much easier to use, and a home workstation can deliver usable, qualitative results. However, this requires a lot of time and dedication. I’ve spent endless nights refreshing my knowledge on CFD, and fine tuning the calculation models, but this has paid-off well when you are able to see your design ‘flying’ in a virtual environment.

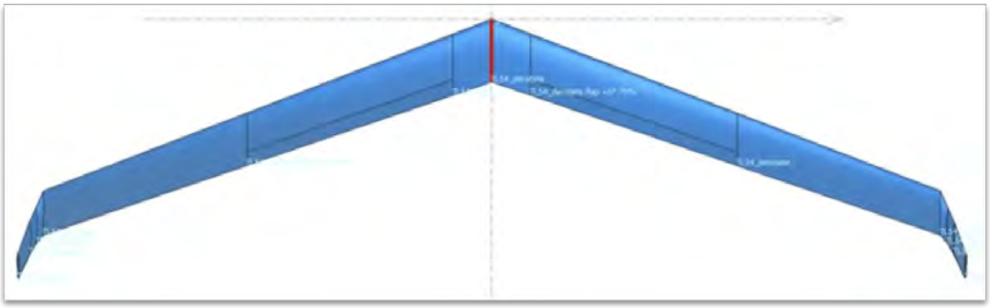


A rendering of the the Dream 2700 'flying' over the beautiful rolling hills of northern Italy.

Wing Design Optimization In XFLR5

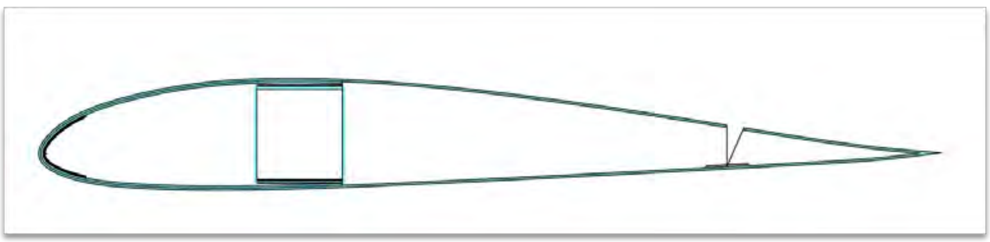
Most of the wing aerodynamic design has been done using *XFLR5* (see *Resources* below). This is a wonderful tool to try different configurations, and run comparisons. My first design attempt focused on getting as close as possible to an elliptical lift distribution, since I wanted to optimize efficiency. In that configuration, winglets were placed at the wing tips, to further optimize the wing, and to give lateral stability.

The choice of the wing section profile required many iterations. The decision needs to be based on several factors: it should be a good section for low Reynolds Number (that for this design is varying from 50.000 to 400.000), should have a decent maximum **C***l*, and a low moment coefficient (**C***m*). An higher **C***m* will require an higher wing twist to reach the desired stability. The Reynolds Number (Re) is non-dimensional and can be described as the ratio between inertia forces and viscous forces. The lower the Re, the higher is the viscous effect of the air. Low Re usually lead to higher risk of separated flows and laminar bubbles. This can produce bad aerodynamic characteristics.



The initial wing shape with nearly elliptical lift distribution.

The final choice went for a section developed by Thorsten Lutz, the *TL-54*. This wing section offers a good maximum **C***l*, a quite low **C***d* and low zero lift moment coefficient (**C***m0*).



The TL-54 wing section, designed by Thorsten Lutz.

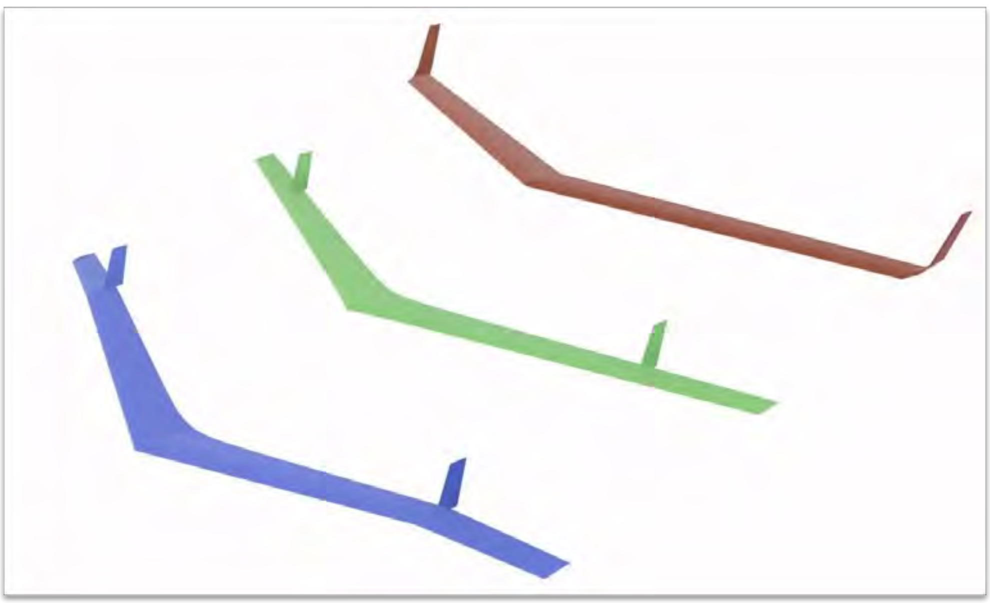
XFLR5 was used extensively at this stage to optimize the wing twist and planform. This tool allows you to test various configurations and make comparisons, by changing several parameters. I will not go into all details of *XFLR5* calculations, since this has been already published in legacy RCSD in various great articles. All aerodynamics parameters were optimized, including a rough stability calculation.

At this stage, I was quite happy with the wing design, and I was ready to start the construction drawings.

The Bell-Shaped Lift Distribution

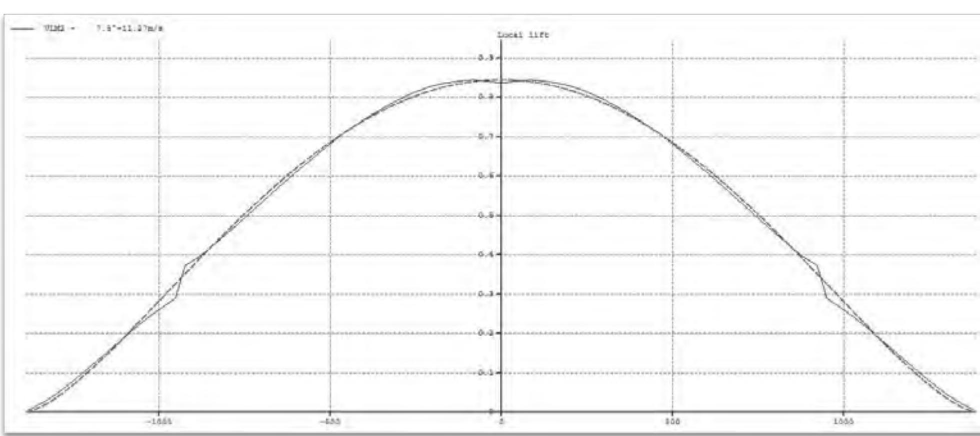
When I was close to freezing the design, I got to know about Albion Bowers, and his experiments with the *Prandtl-D* design. In a nutshell, Albion studies are demonstrating that, for a given payload, the lift distribution that gives the lower induced drag and the lower structural weight is the bell-shaped one. And, not to be neglected, this lift distribution gives the advantage of a coordinated roll-yaw motion, resolving one of the biggest issues we always had on flying wings, the adverse roll/yaw coupling. To better explain it, an aileron roll input to the left, will at first produce a yaw moment to the right, making the turn manouvre somewhat un-coordinated. I was so excited about this study, that I decided to modify my wing accordingly, and give it a try. With some suggestions coming from Albion Bowers, some support coming from Marko Stamenovic, the *Horten Flying Wing Believers* Facebook group (see *Resources* for links to all of these) and again a long series of *XFLR5* simulations, I came out with my final wing design!

In the picture below, you can see the design evolution.



From elliptical lift distribution (red), to bell-shaped lift distribution (green) and seagull dihedral (blue).

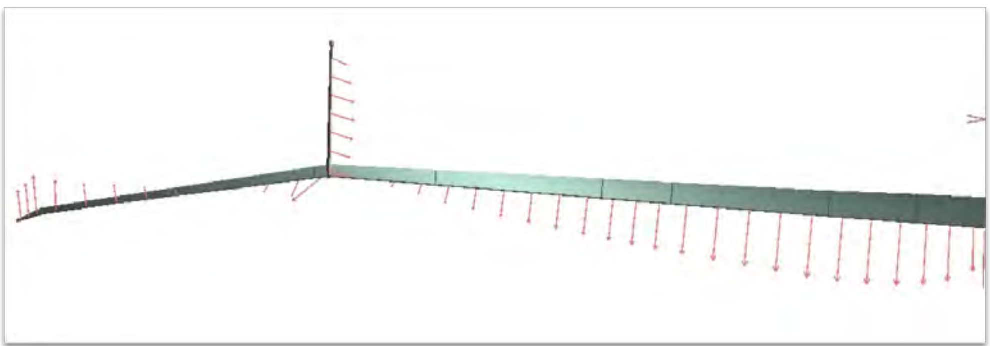
And this is the local lift distribution I got in trimmed conditions:



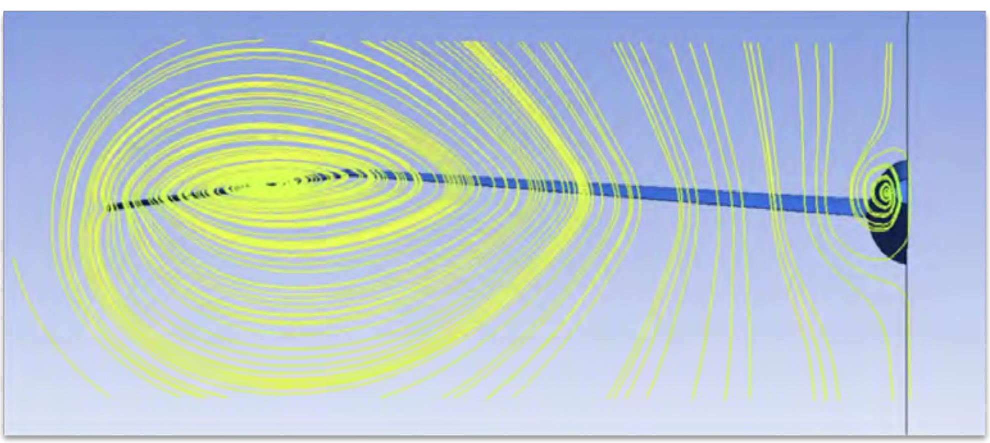
Bell-shaped lift distribution. V=11 m/s, CL=0.53, Alpha=7.5°

I fell in love with that design, for several reasons:

- There's no reason anymore to implement winglets. They are very nice, but their location at the wingtips generates heavy loads on the wing, and increased risk of flutter.
- Vertical fins located where the downwash vortex roll-up core is found. Theoretically, a flying wing with BSLD, does not need fins for stability. Nevertheless, if you want a good amount of lateral control, you need some form of rudder somewhere. Not really a must for a scale RC model, but if your aim is to build a full scale one, think about yaw control authority during take-offs and landings.
- Wingtips are unloaded, and this allows for a lighter wing structure.



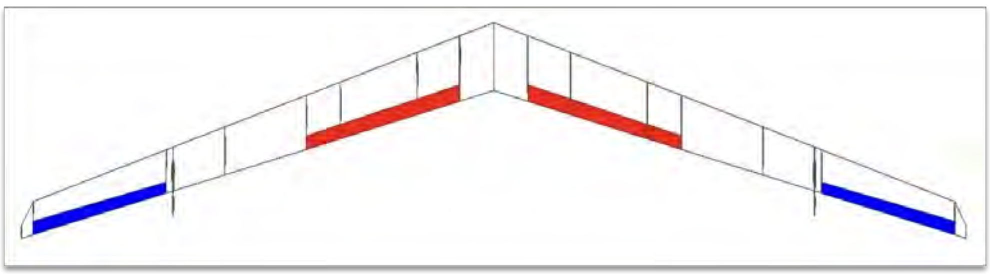
Downwash and upwash as simulated with XFLR5. Notice the effect of the circular vortex on the fin.



Wing vortex roll-up as simulated in CFD. Notice, close to the fuselage, a vortex generated by the fuselage interaction with the wing — would be better not to have this.

As a final design choice, I wanted to explore the 'seagull' dihedral, in conjunction with a special shape for the elevons. Elevons are located after the fins, towards the wingtips, and the local elevon chord increases from fin to tips. Those two features, should further improve pro-verse yaw.

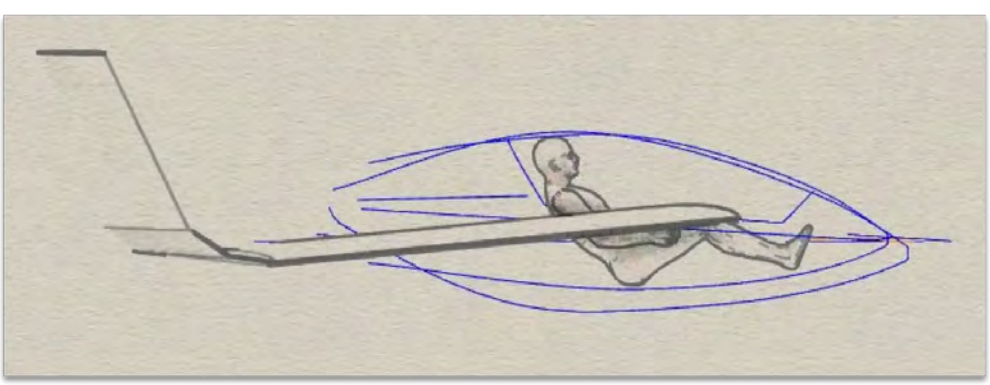
Another special feature I wanted to try are the pitch neutral flaps: if the flaps extension is correctly positioned against the wing neutral point (NP), we should be able to get no pitch moment when flaps are extended.



Final planform configuration: flaps in red, elevons in blue. Note the elevon chord increase at the tips.

Fuselage Pod Design Optimization

As you may recognize from the first article, the fuselage cross section is quite big, if compared to what would be really required for a radio-controlled model. This comes from the fact that I wanted to accomodate a real pilot on the full scale airplane, keeping as well enough space for the electric motor and batteries, retracting gear, and various accessories. Therefore I decided to draft the fuse at full scale, and after to scale it down to the 1:5-scale model.

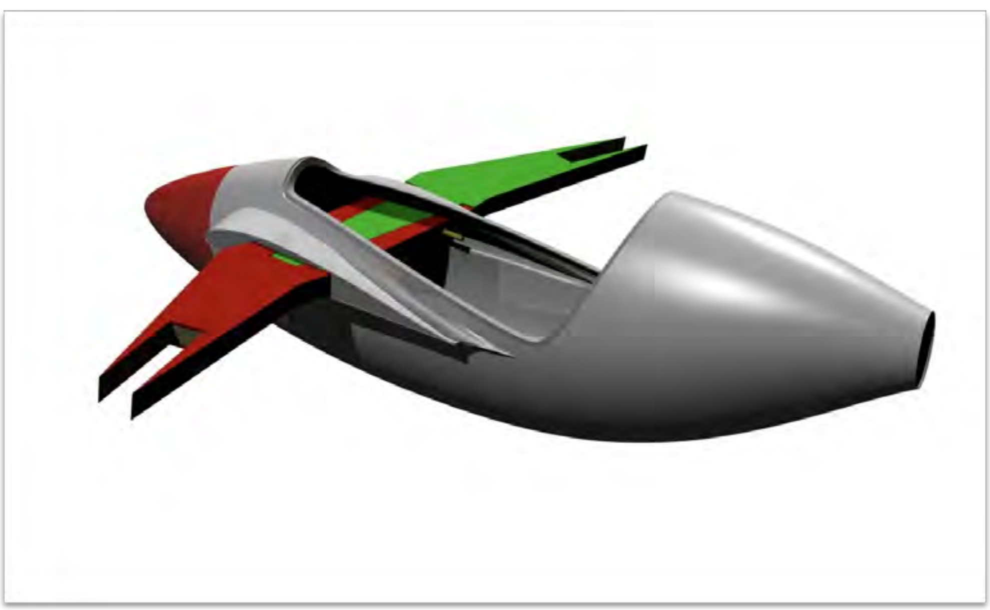


Preliminary sketch of the fuselage pod. The wing is still the old design.

With the perspective of a full-scale glider, more requirements needs to be taken into account:

- Wing spar intersection with fuselage: you need enough space to accommodate pilot legs, wing spar and control systems
- Wing tips should be high enough on the ground, not to touch down during take-offs and landings (remember that we have a swept wing)
- Fuselage to be streamlined considering the wing trim angle, to minimize flow separations
- Fuselage/wing junction shall be optimized to reduce interference drag and again potential separation
- Pilot visibility should not be heavily limited by the wing
- Enough space for the retractable gears
- Being an electric motor glider, we need space for the battery compartment

The picture below gives you an idea of how much space is necessary to accommodate the wing spar joiners. Swept flying wings are subject to heavy torsional loads, and flutter can easily occurr if the wing structure is not rigid enough. Since the wing thickness was quite limited (wing section at the root is 10% thick), the only solution was to extend longitudinally the main spar box, as much as I could.

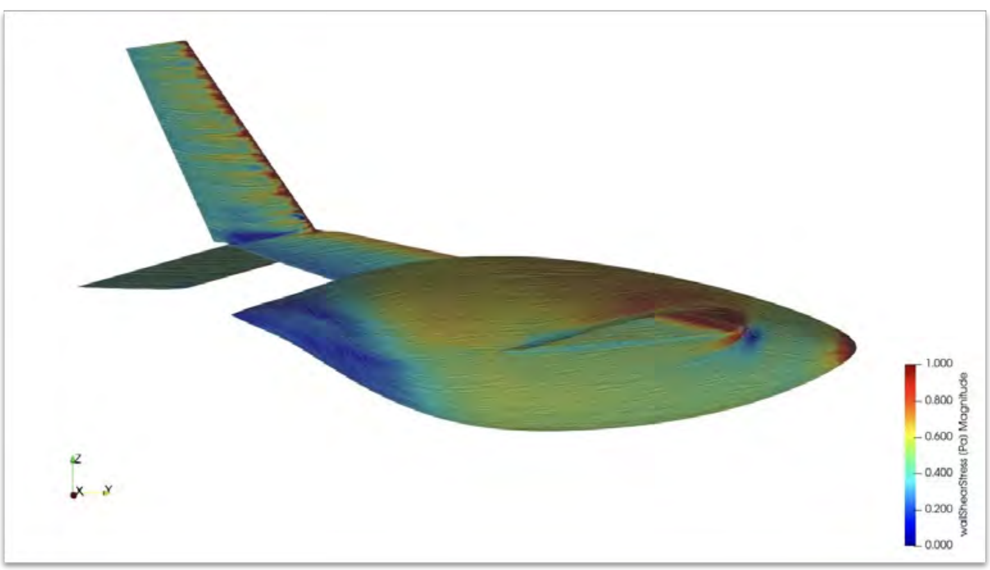


Wing spar and joiners configuration.

During the development, I was able to run some CFD simulation, that allowed me to optimize the wing blending with the fuselage. Running it on a home workstation, you cannot expect miracles, but nevertheless it was very interesting to highlight some potential design flaws.

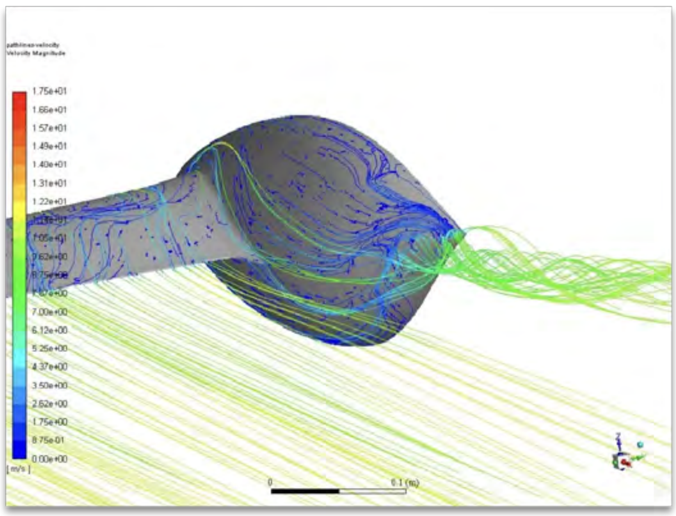
When it comes to aerodynamic drag, one of the worst enemies comes from adverse pressure gradients. You usually have no issues until the air flow on a surface is accelerating: this produces a stable and potentially laminar flow. On this scale model, considering a trim speed of circa 10 m/s, we get Re = 300.000 on the fuselage. For such a low Re and if the surface finish is smooth enough, laminar flow is likely to happen, which is good, but at the same time there's an higher risk of getting a laminar separation bubble, which is bad. On the other way around, a higher Re number will produce less separation issues, but most probably a turbulent flow.

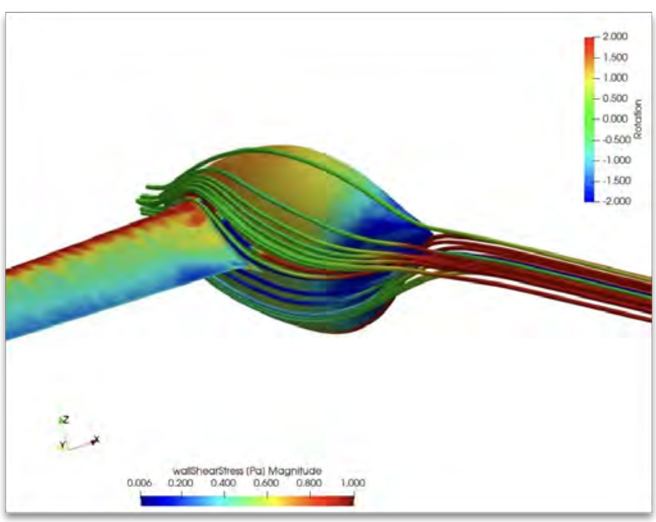
On the *Dream 2700*, it looks like we have a potential separation issue at the back of the fuselage. Let me explain the physics with the help of some pictures:



CFD simulation of the oil flow streamlines. Colors represent the shear stress on surface.

In the area highlighted in blue, the flow speed is close to zero, and this is a clear sign of flow separation, highlighted as well by the chaotic flow in that region. This is due to the poor pressure recovery, caused by the abrupt cross section change in that area. Additionally, as can be see on the next picture, the wing is producing a strong energetic flow, from top to bottom and from outboard to inboard. The strong curvature at the bottom of the fuselage creates a low energy flow with few possibilities to keep it attached to the surface. Practically I designed a perfect ‘diffuser vortex generator’. One of the reasons is connected with the need to position the propeller far away from the ground during takeoff and landing: this is the main reason why the curvature of the fuse is very mild at the top, and very pronounced on the bottom part.



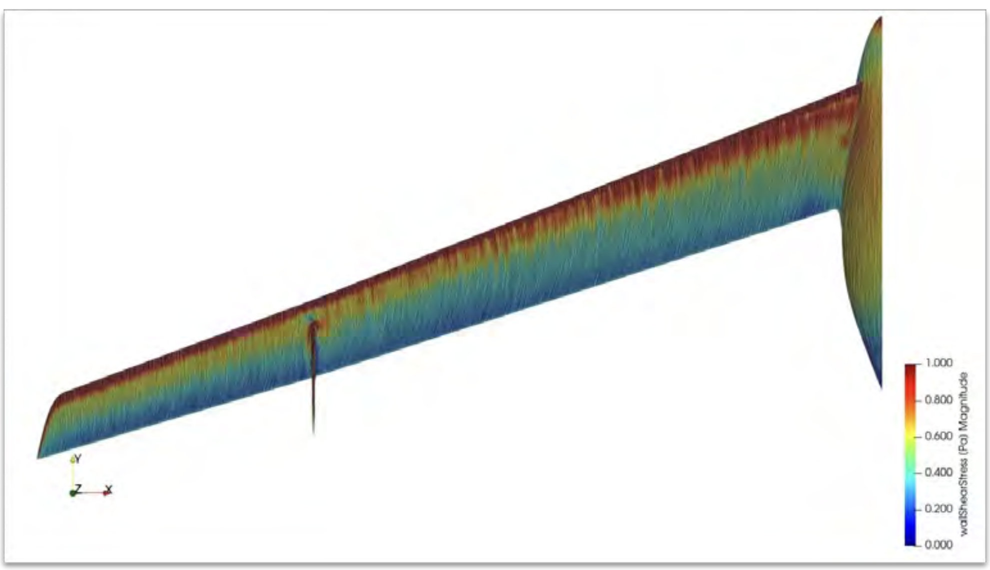


Left: Vortex detaching from the back of the fuselage, energized by the wing flow. First preliminar CFD run. | Right: Final CFD run, with a better model resolution. Red color on streamlines at the tail represents fluid rotation.

Unfortunately, those results were available only after the fuselage had been already manufactured, so I will have to stay with that. During flight testing, I will try to run some experimental flow visualizations to confirm this phenomena.

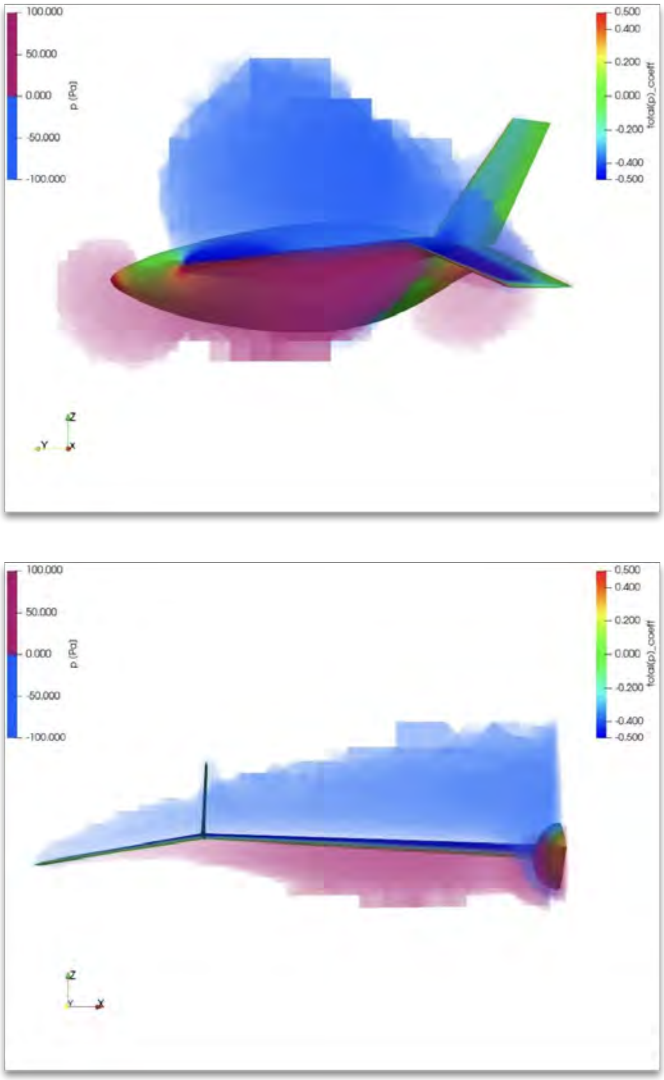
In any case, I'm quite happy with the wing/fuselage blending, where the CFD analysis did not show any special problem.

A very interesting phenomena is highlighted in the pictures below. Swept wings are characterized by a cross-flow, a component of the air flow going from root to tip. This happens on the top surface of the wing, generating a deterioration of the boundary layer towards the wing tips. In that specific design, the cross-flow is more evident before we reach the vertical fins, and less evident from the fins to the tips: vertical fins are acting as wing fences, reducing cross flow at the tips. The negative twist at the tips counteracts cross flow, as well as the fins.



Oil flow streamlines on top surfaces.

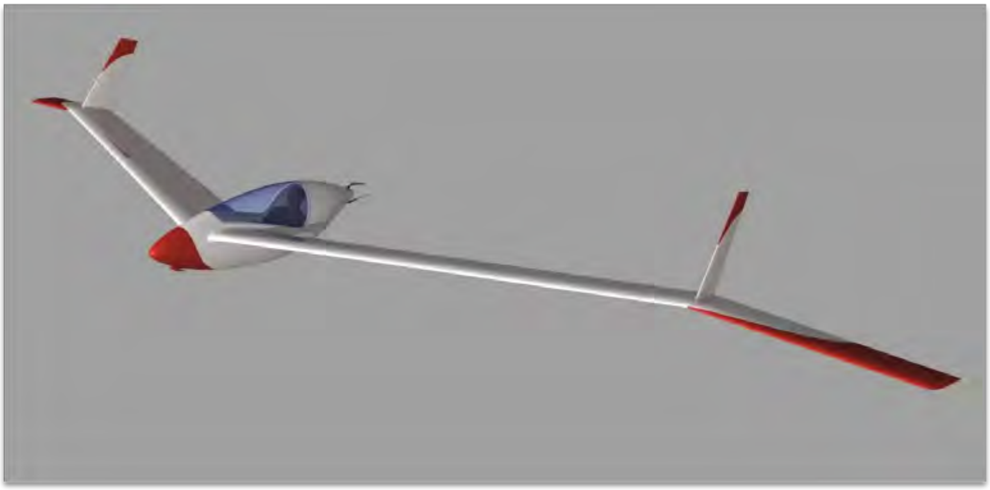
In a last picture, there is something somewhat funny. Have you ever wondered where lift and drag comes from? Well, CFD analysis helps in visualizing lift and drag in a very intuitive way. In the following images, red areas are representing high pressure volumes, while blue areas represents low pressure volumes.



Left: Pressure distribution volumes around the glider. | Right: Qualitative visualization of the lift distribution along the wingspan.

And this brings me to the end of Part II of the Tailless Tale. The next part coming up next month in the *New RCSD* will be dedicated to the construction, where I will share all the steps of the process, with pictures and videos.

Let me close with the rendering of the full *Dream 2700*, with the final colour scheme I will use.



The Dream 2700 final design.

The Slingsby King Kite

Except for lettering and other other external markings, this magnificent ship is ready to go!

Part VI: Final Building Steps and the First Flights

*This is the sixth and final part of this series. Readers may want to the review **previous parts** before proceeding with this article.*

The pilot would be very visible so it was a challenge to make a proper job of it. My sister offered to make clothes but then I had to have a body first. I used my own measurements (only slightly Photoshopped!) and made parts from 10mm balsa. In the elbows and knees I fitted Robart hinges, the hips and shoulders were fixed with shock cord. In this way you get a figure that can be positioned naturally. To attach the pilot's balsa boots I glued a piece of M2 threaded rod fitting into a plastic tube (that is, the control rod stuff) in the poor man's lower leg. A small bend in the M2 wire provided some friction. The hands were fastened into the arms with 1mm copper wire and the head was adjusted into the chest with a 10mm beech dowel and some Velcro as friction. Hands, feet and head remained removable to make it easy to get him into his clothes.

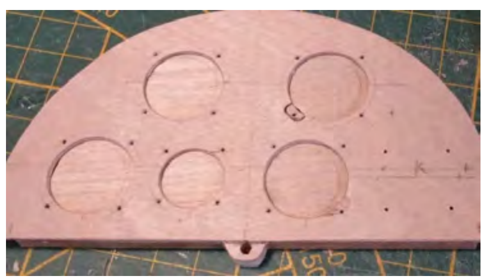
The pilot's head was made from Sculpey a kind of clay-like plastic, which must be baked at 140C to harden it. The tutorial *Sculpey 101* (see *Videos* below) gives a wonderful explanation how to do that, but it still was a time consuming job.

I started with a beech dowel of 10mm and wrapped aluminium foil around it. The head could not be solid as it might crack when baking. I formed the head adding thin layers of sculpey. It took a while but I liked to work on it and seeing how it really started to look like a person.

Left: Pilot in the making. | Centre: Ready for the clothes. | Right: Head modelled in Sculpey, a nice job during a camping holiday.

The instrument panel, just like the pilot, would be in plain sight. The problem here was that information about it was nowhere to be found. One photo showed a tiny piece and the panel seemed to be white. I also detected a white panel on a photo of a *Petrel*, so that was feasible. I decided to make a good job of it. Looking at the other gliders of Slingsby I had already ordered a set of instruments in 1:4-scale from *AeroCockpit* (see *Resources*) but I could not use the dials. I still had pictures of the dials from the previous plane, the Slingsby *Gull*. On the photo of the white instrument panel of the *Petrel*, the instruments were countersunk and I decided to make something similar. The instruments from *AeroCockpit* were delivered as a superstructure, but could be cut off.

Now I could make the panel proper. It was is made of two layers of 0.6mm plywood. After having marked everything, I drilled all the holes with a 1mm drill, including the centre of the holes in the panels that were clamped together. Then I cut the plywood on the front and back with a cutting compass, cut segments in it and could break out the plywood. I glued the two panels together with a few dowel pins. Then the holes turned out to be just a bit too small for the instruments and with the tapered handle of a screwdriver and some sandpaper I made them fit exactly. I glued another plate behind it together with two magnets to secure it into the plane.

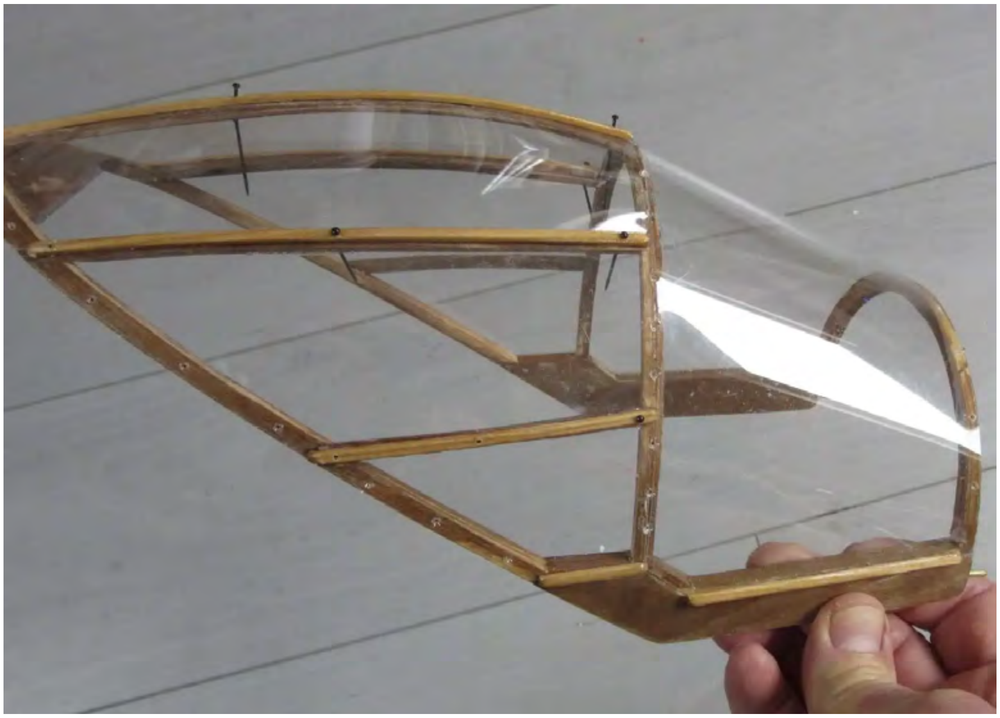


Left: Three layers of plywood. | Centre: Now sprayed white, all loose parts lying on my bench. | Right: Fastened with two magnets, behind it the receiver battery.

I cut off all the instruments that had been built up so that only the bezel with the glass was left. But the compass should actually be a sphere. On *Retroplane* Eric Spore had already done something like that and it was a nice detail. So I rounded off a handle of a file, clamped a piece of PET (clear plastic) on a board with a hole, heated the plastic, pushed the file up and a tube over it and — *lo and behold!* — a nice sphere. I glued a strip of a photo of the compass in it and painted the sphere black on the inside. I also made the screws from black pins, filed the heads flat and made a saw cut. Now I had all the parts. All that remained to be done was the fun part, gluing everything together with PVA.

A nice detail: a real spherical compass. Clamped a piece of PET, heated it and then pushed in a round shape from below and a piece of suitable tube over it from above. In this case a file handle and a piece of fishing rod.

The instruments also needed the pitot tube, which I liked to be demountable. I made it from solid 2mm wire which was lying around. I don't know exactly what kind of stuff it was, but it was not magnetic. I took two pieces, bent them to look like the example and soldered them together with silver. I left one piece of wire sticking out and put a triangular brass plate on it together with a square piece of brass tube. Finally a piece of iron and soldered it all together with silver. The brass square tube fitted into just in a larger tube, in which I glued a magnet. The larger brass tube is glued into the fuselage nose with 5 min epoxy from the inside. I had to hold the fuselage upside down to glue it into place, good for my body flexibility!



Cockpit canopy lined with panels of 0.5 mm transparent plastic, bent only in one direction.

I hesitated about the skid but decided to make it massive, not sprung. I glued 12 layers of 2mm balsa with PVA using the fuselage as a mould, separating with cling film. After curing, I took it off and planed it into shape and covered it with *Diacov (*see *Resources*) to imitate the sailcloth of the skid of the real glider. Then I painted it white and glued it all on the fuselage. On top of that I glued the skid itself, made from 0.6mm plywood and two layers of 2mm pine. Then 2x2mm pine strips in the corners, to imitate the battens holding the canvas.

Back to the interior for a moment: I covered the seat with leather from an old wallet and made a control stick from aluminium tube, which slides over a piece of installation wire so that the stick could be bent into the desired position.

Ready for first flight, sunny in the garden, no lettering yet.

Apart from some details of the interior, the model was now ready. I had calculated the centre of gravity (CG) with *cgCalc* (see *Resources*) and it had to be 79 to 90mm from the front frame. I had to use 450g ballast, of which 130g could be removed in the white jar. In this way the CG could be adjusted between the two values without having to chop or break. Epoxy resin was poured over the loose lead pieces. And, yes, the weight of the epoxy was deducted.

Some more data of the model: span 3875cm, weight 4800g, wing area 85dm² and that gives a wing loading of 56.4g/dm².

My model was now almost ready to fly. I did some paint work on the pilot and some details on the interior, found with some searching and help from *Scale Soaring UK* (SSUK), the right lettering which my friend Adri Brand was able to cut the lettering which went on easily.

And then, suddenly, there was the opportunity for the first flight. The weather forecast was good, Rob Ten Hove offered to tow, Adri would coach me and Raymond was at the ready to do the photo and film work. That Friday there was quite some wind at the field. It was chilly and the sun to weak to break through completely. Rob's *Eco Boomster* had no trouble with the *King Kite*. I had to trim the aileron quite a bit because of the strong wind.

Left: Nice slim wing with a subtle gull wingtip. | Centre: We stand there a bit tense, but it flies fine. | Right: With flaps half out well controllable to the landing. (credit: Raymond Esveldt)

After releasing from the tow and elevator trimming there was the moment of truth: the plane flew really well, tight and responsive, stayed on altitude fine and was a pleasure to fly. Of course there were no thermals, but I think that will be fine, too.

Another thing about the flying characteristics of scale gliders in particular: on a slope there is usually enough lift. However we don’t have slopes here and, incidentally, not many thermals close to the coast either. That’s why it is very nice that it has a decent sink rate.

The real *King Kite* had a pretty modern profile, which is why the *HQ 2.5* airfoil of this model is not very noticeable. After a few minutes we had to land with flaps and ailerons slightly up — the real one didn’t have the latter.

Left: The King Kit flies very well.l | Centre: Some aileron trim, but otherwise, just flying beautifully. | Right: Landed fine, I was very happy he flew like that! (credit: Raymond Esveldt)

The maiden flight of the *King Kite* was captured by talented videographer (and frequent contributor to the *New RCSD*!) Raymond Esveldt in a short film entitled *Slingsby King Kite 1/4-Scale First Flight* (see *Resources*). The video shows how happy I was that it flew well because the aerodynamics are sometimes hard to predict.

Apart from a few minor details my *King Kite* is ready. I would like to thank everybody who provided assistance and *Modelbouwforum* (MBF), *Retroplane* and SSUK for all the help. Especially a big thank you for Adri for all the milling and lettering, to Rob for towing and to Raymond for the photos and videos.

Additional build details can be seen on MBF in Dutch as well as on *Retroplane* and SSUK in English. Also, the *King Kite* flew on a tow meeting in Kampen, Netherlands and performed very well. All are linked in *Resources* and *Videos*, below.

I am really pleased with this scale glider and I thank you for reading about it these past months.

Good luck with your projects and see you all again soon!

How Many Degrees in a (GPS) Triangle?

Remember my daughter (and designated hi-start retriever) Laurel from that picture in Los Alamos in Part I of this series? They grow up so fast!

Part II: Well, you know, life.

For those who have not yet done so, you may want to read the first article in this series before proceeding with Raymond's next instalment. — Ed.

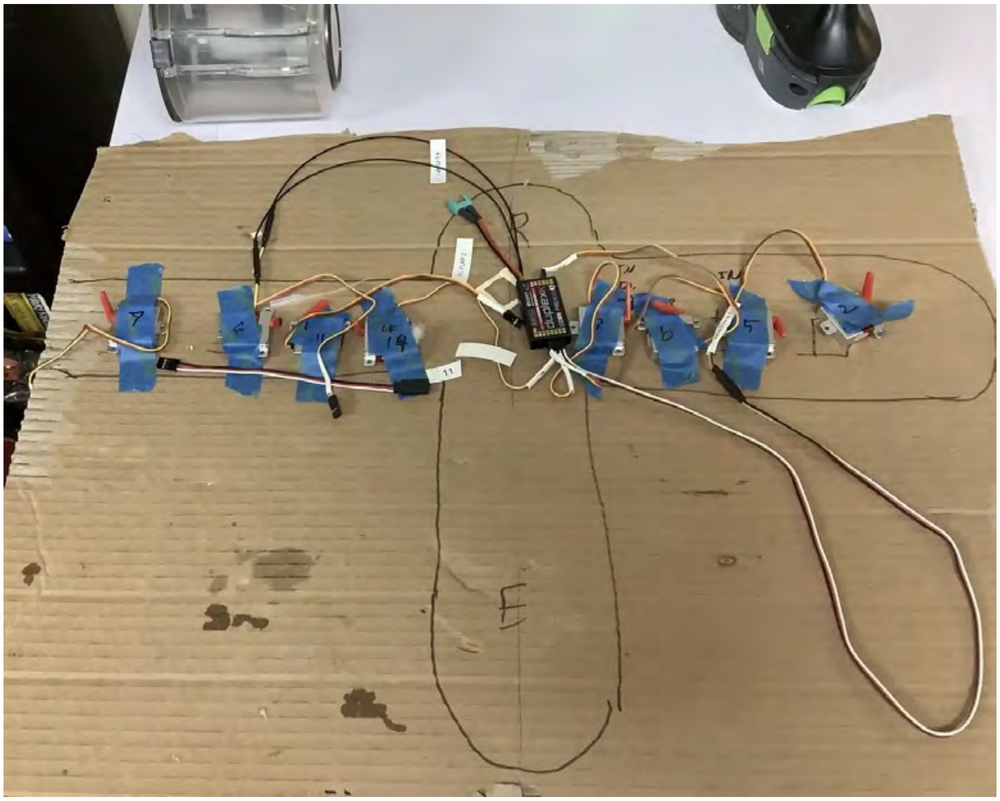
When I last actually got an article out to the ever patient editor there was great hope that I would be flying my GPS Triangle Racing† Sport Class plane at the *Fall Soar for Fun* at HighPoint Aviation Airfield in beautiful Cumberland, Maryland (see *Resources* for links). Not so much. Life is funny, so I barely got to fly this summer. But, things are much more stable, and I am pretty sure the light at the end of the tunnel is **not** a train.

So, I am sure you have thought of nothing else besides "what plane did he get?" I did a lot of research and ended up with a Valenta Model *Thermik XXXL* 5m. She is an older model, around 2009, but seems to be an economical yet effective entry point to GPSTR. Older or not, she is a beautiful, well-made ship. It is my first time rigging up an eight servo wing and also a 5m ship is just **big**. How big? I either needed a new car or a full size roof top box. I tried to reason with my wife that a new car/SUV is absolutely required to carry my new plane, but she did not buy it and so roof top box it is — for now at least.

†Okay, side note: can we just agree to call it GPSTR or GPS-TR? I don't type that fast!

Left: This is my VW Golf with a 3.5 meter. When I try to put the 5m Thermik in there, I have no room to do important things like shift (yes, it's a manual!) | Right: No pictures of the roof top box, but here is a picture of the boxes box. Grandson #2 not included.

I mentioned that I am a JETI guy and the YouTube videos by Harry Curzon (link in *Resources*) have been a life saver to figure get the most out of the these radios. On one of his videos he had his plane 'bread boarded' on cardboard — yes I know he is not the first — so he could see how things were going with his programming. I did the same for my initial set-up, but unfortunately that is where that part of the project sits.



The avionics on the cardboard ‘bread board’.

I have been a HAM radio operator (N1LUL) for many years and would say I have better than average soldering skills, but the thought of making the harness for the wing made me nervous so I contacted *soarerf3j* who I saw on RCgroups sailplane classified and we started communicating about what I needed. Super nice guy and made sure that everything was in order before he started the harness. I quickly received the harness and it is a work of art, so much nicer that I could have produced and at a reasonable price.

However…

His harness is a DB9 connector for each half of the wing, but the kit was molded for a single db15 connector. I once again contacted *soarerf3j* about redoing the harness with a single connector, but his logic for using a connector for each wing half is strong. So my challenge is to figure out a way to securely mount two DB9 connectors in the wing and fuselage. The easy way would be to hard mount one half and have the other half free floating. The harder, but in the end better, way will be to just suck it up and engineer the mounts so as I put the wing on the connectors mate. I did ask for a 3D printer for Christmas which could help me out in this endeavor. Any ideas?

I need to put two of these in the wing mount area.

As I write this it is Thanksgiving and I **really** want to have her flying in the Spring, again over in Cumberland. I have 90% of the stuff I need to complete her, so it is up to me. I did get all of the juicy electronics I need to make her a GPSTR plane, but I have not even opened the box. If you all will stick with me, I'll update you on the progress through the winter. Knowing that my dedicated fans are waiting on a update will help me keep the momentum up.

Wish me luck, thanks for reading and see you next time!

Resources

- *HighPoint Aviation Airfield* — "The general area along the road going up Knobley Mountain to the airfield is known as High Point

Acres…it naturally followed that the airfield could be called High Point Acres Airfield…”

- *Thermik XXXL* from Valenta Model. — “The experience with handling this model is very similar to flying a real glider. The model is suitable for flying in big slopes…”
- *soarerf3j* on RCGroups. — “F3X/F5X/scale sailplanes custom made wiring harnesses…”
- *Sailplane Classified* on RCGroups.
- *Harry Curzon* on YouTube.

All images by the author. Read the next article in this issue, return to the previous article in this issue or go to the table of contents. A PDF version of this article, or the entire issue, is available upon request.

We All Need Friends Like These

Happy days, post maiden flight.

A little story to reaffirm your faith in humanity.

For nearly the past four years I have been the very proud owner of an *Enigma* F5J 4m, 1.5kg full carbon glider. A few weeks ago we had a little gathering in the centre of Israel. About ten glider guiders from the *Quiet Flight Club* having a nice day out. However on my first flight of the day, 30 seconds into the flight, I crashed.

I was gutted.

It was apparently caused either by a faulty BEC (battery eliminator circuit) or faulty wiring to the BEC. Either way, not something I have on my pre-flight checklist, although I will now. It was quite unnerving. Flying along nicely, and then a few seconds no reply to input, followed by normal business as usual. As soon as I noticed this, I tried to land, but she augured in from 50+ meters high, about one kilometre away. The walk of shame went through high spikey greenery.

The bits ‘n pieces. If this was yours, wouldn’t you just cry?

I was inconsolable for two reasons: first, it wasn’t a flying error, I didn’t do anything stupid; I could have accepted that. Second, the damage was very extensive. Apart from the tail group, I could see cracks and breaks everywhere. And currently I am on low-to-no funds for anything RC related, with a bleak outlook for the coming months at least.

The bits and pieces were loaded into a friend’s car, together with my radio. He was going to see if he could replicate the problem, and if not to put the receiver in a cheap foamy and using my radio, fly it high and far.

I didn’t want to know. Actually, until last night the flight bag and wing covers were still in my car; I couldn’t get myself to take them out of my car and put them in storage.

Fast forward a few weeks, and we had an evening lecture on building materials, glues, the forces we work with and the rules of F5J competition. During the break there would be ‘a special presentation’, whatever that meant.

Unbeknownst to me, seeing me and the state I was in after the crash, the guys got together. Some donated materials, some donated time and expertise, some donated money. And they did a monster job in bringing my *Enigma* back to flying condition again.

Here's me holding the repaired Enigma along with a few member of the Quiet Flight Club. Appropriately the 'new' Enigma has a sticker of a rising Phoenix!

Still waiting for some parts for the geared motor, but we should be up, searching for thermals in the near future again!

Left: Me and the Enigma, pre-crash. | Right: Come and look us up when you’re in Israel!

Science for Model Flyers

Stress testing a glider wing to ensure its ability to withstand the considerable aerodynamic forces generated in flight. (credit: Institute of Aerospace Engineering, Brno University of Technology)

Part II: Forces and Inertia

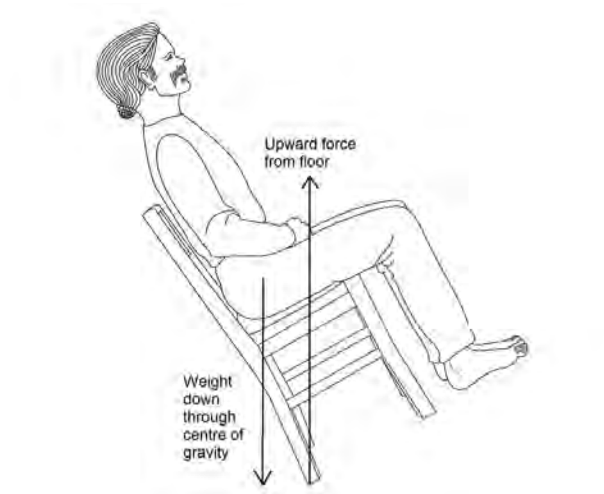
Although it is not a mandatory prerequisite, you may want to read the first Part I in this series, The Periodic Table before proceeding with this next instalment. — Ed.

Now we turn attention to forces and inertia. Should anyone think these ideas are a little abstract, many of them will be used in future articles on structures and machines. Consider this article as a good prerequisite for those upcoming articles in this series.

Forces

What is a force? This not the place to talk about the origins of force, for example the curvature of space-time resulting in the apparent force of gravity. Let's stick to the everyday meaning, namely a push or a pull. As you will see a force can change the forward movement of an object or the direction of that movement and two forces can also change its rotational movement or shape and can even break it.

Physicists like me can have a strange view of the world. As always there is a German word for it — *weltanshauung* or 'world view'. If I watch someone tilting back on a chair I imagine his weight force acting down through his centre of gravity. I know that when it is further back than the pivot point of the back chair legs he will fall over backwards (Picture 1). A normal person will just enjoy the sight without thinking about it. Of course I laugh as well but know why it happened. In the same way I imagine the forces on models.



Picture 1 (credit: Adapted from Crazy88MMA.com)

Forces Relevant to Model Flying

This would be a long list if complete. Here are some:

- The aerodynamic forces of lift and drag, the former being created by pressure.
- The mechanical forces of weight and thrust.
- The resistance or inertia of a model to acceleration or turning, which is a kind of virtual force.
- Rotational forces called torque or moment.
- The torque developed by our motors and engines.
- Glide angle, which is determined by the ratio between weight and drag forces.

- The reduced effect of a force at an angle.
- Thrust from our propellors created by accelerating air and experiencing the reaction force from it.
- Vectored thrust from jet engines allowing high manoeuvrability.

Our Automatic Responses

When reading the practical examples in this article there is one important thing to remember. When we fly we don't think about how to move the sticks. We have trained our muscles to do what's needed without thinking. Like playing the piano, if we had to think about what to do we would be too late. So you might think, 'I don't think I do what you describe', but you do.

Mass and Weight

In normal language mass and weight mean much the same. In science they are very different. The mass of something is the total of all of the atoms it is made from, that is to say the protons, neutrons, electrons and other particles that comprise atoms as described in last month's periodic table article. An object has the same mass everywhere in the universe, as far as we know.

Weight is the pull on an object from another object. It depends on how many kilograms each object is (m_1 and m_1) and how far apart they are (d). In maths it is:

F is proportional to $m_1 \cdot m_2 / d^2$

To find F in newton you multiply by the gravitational constant G (6.674×10^{-11})

$F = G \times m_1 \times m_2 / d^2$

As I wrote that I thought, 'You've never done the sums for the earth.' The earth isn't uniformly dense so it won't come out exactly right. Anyway here goes:

m_1 = 1kg

m_2 = 5.9722 × 10^{24}kg (mass of the earth)

G = 6.674 × 10^{-11}

d = 6.36 x 10^6km (average radius of the earth)

W = 6.674 × 10^{-11} × 5.9722 × 10^{24} / (6.36 x 10^6)^2

Adding up the powers of ten (-11 +24 -6 -6) gives 10^1

Multiplying and dividing the rest: 6.674 × 5.9722 / (6.36 × 6.36) = 0.98539

Wow!

In other words 9.85 or 10 in our practical approximation. The difference from the average measured value of 9.81 is no doubt due to the increasing density of the earth with depth.

Our own weight is the result of the earth's gravity. It is less in some places than others. It gets less as we move away from the earth. It is more near the poles because the earth is slightly flattened and we are nearer the earth's centre. In space it appears to be zero because we are pulled equally in all directions by the rest of the universe. On the moon we weigh less because the moon has less mass and pulls us less despite its smaller radius. If we are orbitting the earth we are in free fall so appear weightless. To describe someone as overweight is meaningless scientifically. Take a person to the moon and he or she weighs less. On Neptune much more. In space nothing. To a scientist the correct term is 'too massive.'

Massive is a word that is often abused usually by being taken to mean large. Poor old English is taking a battering at the moment. Exponential growth is now taken to mean rapidly increasing. What it really means is increasing at an increasing rate. Though our savings increase exponentially with compound interest, with current interest rates that is very slow, though that appears to be changing. Another abused word is decimate, which now means destroy almost completely. In fact it was the opposite — a method used by Roman commanders to discipline a rebellious legion. The soldiers were lined up and every tenth man in the row was killed with a sword 'to encourage the others.' No point in killing all your soldiers for mutiny, just a tenth. No-one seems to question the use of 'deci'.

Higgs Space

Our ideas about mass are developing very rapidly. Some physicists are now suggesting that space should be called Higgs Space. Aye aye boson! One suggested that we think of space as like a snow field, which is an analogy or model that was new to me. Though made of snowflakes, viewed from a distance it looks smooth. If we ski we move at top speed without friction. This is like how light and other very low mass waves/particles move at the speed of light. If we put on snow shoes we find it more difficult to move. Which is like a small mass. With only boots on, movement is much more difficult. This is a larger mass with a lot of inertia. Space fights back. If we whack two heavy particles together in an accelerator sometimes they cause a part of the Higgs space to fly out, the famous Higgs Boson. Watch that exciting space. This might mean all of the forces including gravity are finally explained in one thing. Or not.

Mass and weight are different in another way. Mass is just there. It just has quantity or magnitude. It does not act in any direction. Scientists call that a scalar quantity. Other examples are temperature and energy. Weight pulls in a particular direction. So it has two dimensions, magnitude and direction. That makes it a vector quantity. Another everyday confusion is to use kilogram for both mass and weight. Normally it doesn't matter much but to be clear what we are talking about we should use the newton (N) as the unit for force. To give an idea of how big it is, near the earth a kilogram weighs about 10N so a medium apple is one newton. Bearing in mind Isaac's malic inspiration it's a nice touch isn't it? In old units mass would be pound and force would be poundal, with one pound near the earth weighing about 32 poundals. This multiplier is given the symbol g or and called the acceleration due to gravity. A falling mass accelerates at 10 m/s² or 32 ft/s².

The equation for weight W is $W = m \times g$ (g is approximately 10 as we calculated above).

Now to look at what types of force there are and what they can do.

Static Forces

Forces on a fixed structure, such a house or a bridge, must balance or the structure would move. These are called static forces. For a large structure standing on the ground upward forces must act together to balance its weight. Such structures are usually made of many component parts each of which carries part of the load. Some parts are vertical, some at an angle and some horizontal. The last won't carry weight but will hold together other components that do.

Even in pre-university physics, students learn how to calculate the forces in each part of a structure. Exactly the same analysis can be done in our model aircraft as you will see in a future article on structures.

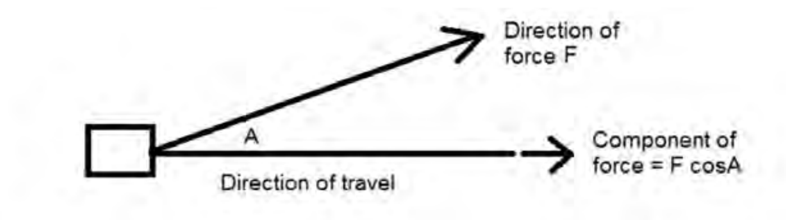
Dynamic Forces

These cause change in motion. Newton's first law of motion tells us that a mass continues in a straight line at constant speed unless a force acts on it. We will need to understand that when we consider a glider flying downhill at constant speed.

Forces at an Angle

One idea we need now is resolution of forces. Force is a vector quantity meaning it has both size (magnitude) and direction. We know intuitively that we get the best effect if we push or pull something exactly in the direction it is free to move. A force at an angle has less effect. Resolution means finding the effect of a vector, such as force, at an angle.

Picture 2 shows us an object that is pulled by a force at an angle *A* to its direction of travel. The effect of the force is called a component and is equal to $F \times \cos A$. If *A* is zero degrees then $\cos A$ is 1 and the whole force will move the object. If *A* is 90 degrees then $\cos A$ is zero and the object won't feel any forward force.



Picture 2

Here is a table of the effect of angle on a force:

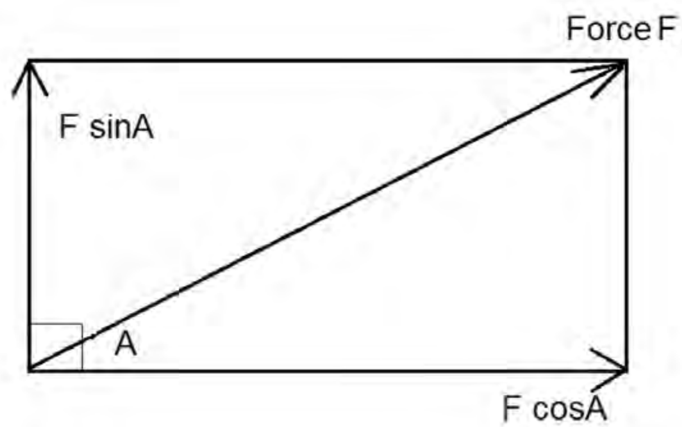
Degrees	% of force (approx)	Degrees	% of force (approx)
0	100	45	71
10	98	60	50
20	94	75	26
30	87	90	0

As you see it takes large angles to make much difference.

What is cosA?

It's due to the dreaded trigonometry. Wake up at the back there!

The theory is shown in the rectangle in Picture 3, that models the example above. There are two right-angled triangles. The applied force *F* is the diagonal hypotenuse.



Picture 3

We can calculate the sizes of the vertical and horizontal forces from trigonometry on the lower triangle. Adjacent is the side next to the angle. Opposite is the side furthest from the angle.

Horizontally:

- *Cosine* = *adjacent* / *hypotenuse*
- So *adjacent* = *cosine* × *hypotenuse* or $F \times \cos A$
- In the above case this is the component that speeds up the object

Vertically:

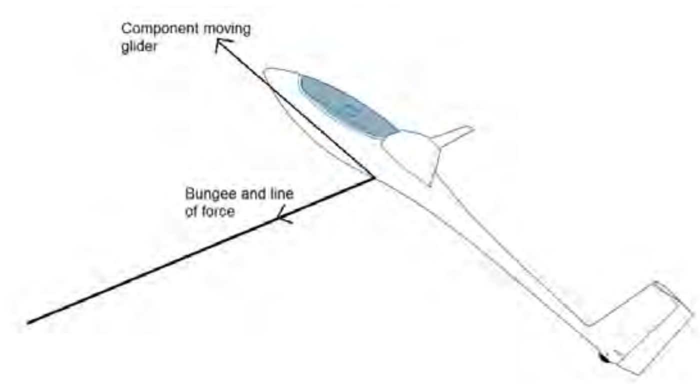
- *Sine* = *opposite* / *hypotenuse*
- So *opposite* = *cosine* × *hypotenuse* or $F \times \sin A$
- In the above this component that has no efffect on the object

The two partial forces are called components. You could also find them by doing a scale drawing.

Practical Examples

Bungee (Hi-Start) Or Winch

As you release the model the bungee angle is virtually zero so acceleration is rapid. Immediately the nose goes up the angle increases dramatically as does the drag. We are all familiar with the stick work needed to maintain both climb and forward speed. Some web pictures show the bungee at right angles to the model in the climb, unlike Picture 4. We now know that this cannot produce any forward force. Only if nearly overhead and ready to drop the line, could a prevailing wind provide airspeed and lift.



Picture 4

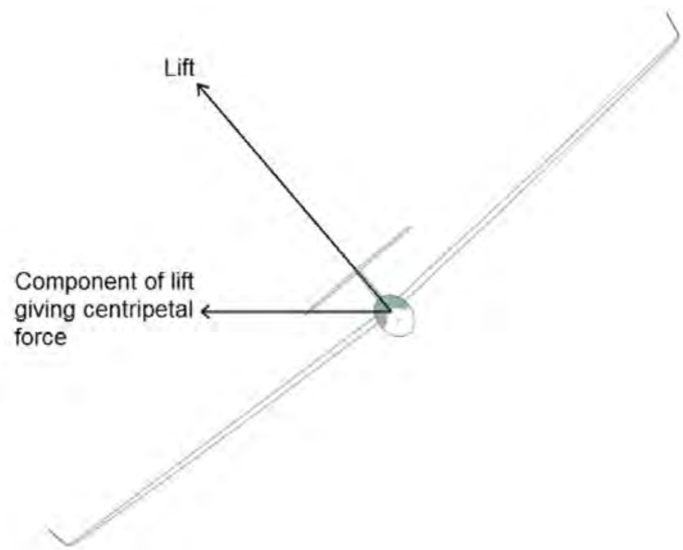
Knife Edge

This is a manoeuvre that is for the power model. Here we effectively alter the thrust line so there is a component of thrust upwards. Whilst it is true that there might be a small lift force from the fin or a flattish fuselage, it is mostly the change in thrust line that maintains height as you can see from the right-most image in Picture 5.

Picture 5 (credit: FlyRC.com)

Circling

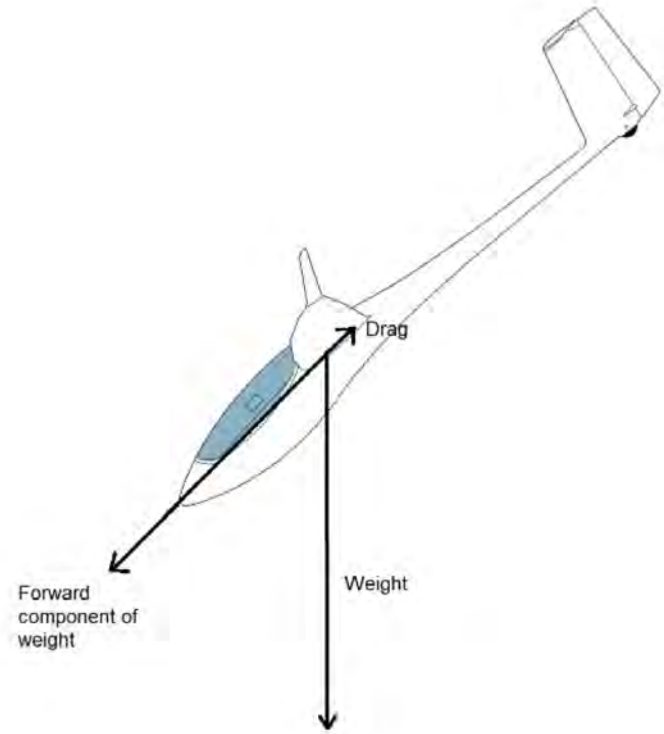
When a model banks and turns due to ailerons there is component of lift that acts towards the centre of the turning circle as shown in Picture 6. This force pushes the model sideways. The steeper the bank the greater is the percentage of the lift pushing sideways. There is now a smaller lift component to hold the model up so we instinctively apply up elevator so the model doesn't lose height.



Picture 6

Dive Angle

A glider is always diving. That's where its energy comes from. Mostly the dive angle is small, being just enough to overcome drag so Newton's first law tells us it won't change in speed. Hopefully the air it is diving through is moving upwards. When we want to gain speed we go into a steeper dive as in Picture 7. This increases the forward component of weight. The surplus of forward force over drag now accelerates the model.

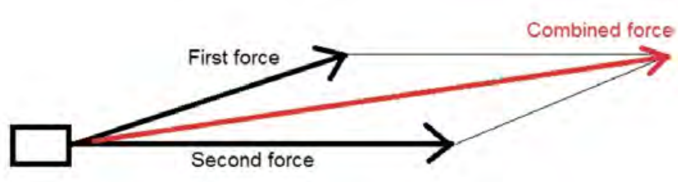


Picture 7

Combining Forces

Picture 8 shows a variation of the diagram in Picture 3. In this case the object is free to move in any direction and instead of splitting the force into two components it is being pulled by two forces. However they are not at right angles to each other, though they could be. Instead of a rectangle we draw a parallelogram. The two components in black act together to produce a resultant combined force shown in red.

If we draw the two to scale, e.g. 10mm : 10N, as the sides of a parallelogram enclosing the angle between them, the corner to corner line gives the magnitude and direction of the combined resultant force. You can find the length and angle of this line either by calculation or by scaling off the drawing.



Picture 8

Practical Examples of Resultant Forces

Slope Traverse

An example would be a glider traversing a slope. As well as the forward motion due to weight there would be a wind force into the slope. When traversing, the model would move towards the slope and we correct that, without having to think about it, with rudder or aileron.

Bungee or Hi-Start in a Side Wind

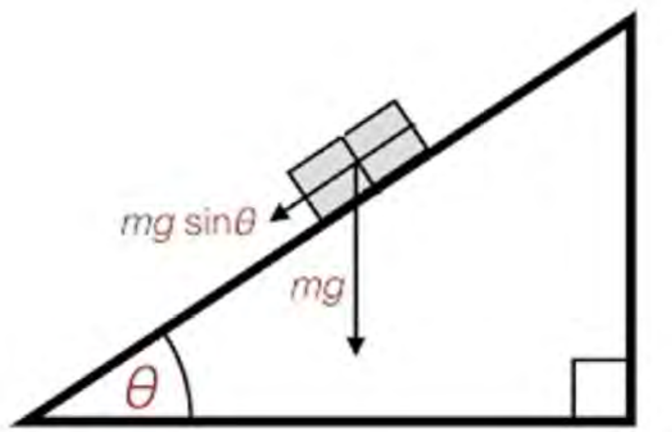
No, you wouldn't normally bungee with a side wind. However some flying sites only have two launch directions, mine being an example. The wind is **never** exactly along the runway and the surrounding fields are cropped not grass.

Buddy Box Training

I do a fair bit of that. The most common takeovers are when the model is getting too far downwind because the trainee pilot has not got the experience to correct for the wind. A close second is the problem with sidewinds when landing as, for safety, the instructor must not allow the model to get overhead nor to drift off the runway.

Forces on a Slope

Picture 9 show the weight of the block is mass times gravity ($m \times G$). Remember that near the earth g is about 10 which is why one kilogram weighs 10N. The component of mg down the slope is the weight multiplied by the sine of the slope's angle, hence mg sinθ. We will use this idea in an experiment later.



Picture 9 (credit: Adapted from Quora.com)

Importance to Us?

A slope, also called an inclined plane, is used in many simple machines such as a wedge and a screw thread. These will be covered in a future article. And of course a glider flying down its glide angle is another example. The above equation mg sinθ applies here too, though in this case it is equal and opposite to the drag. A high performance glider might have a glide angle of 2º, roughly 1:30. The forward component of weight and the drag will be about 3.5% of its weight.

Change of Motion

A single force can a cause of change in velocity (speed and/or direction) though there is a second reactive force from the object called inertia. More about that later. The relevant equation for motion is Newton's Second Law, $F = m \times a$. Notice the similarity with $F = m \times g$. Go on, you work it out. The clue is 'acceleration due to gravity'.

Change of Shape

Two forces can cause a change of shape. An example is a bungee launch (hi-start). The peg in the ground pulls at one end of the bungee and the launch person pulls on the ring or model at the other end. The result is that the bungee changes shape. It gets longer and thinner. Moving a force is called work and takes energy. Energy (work done) is force times distance. The further you walk with the model the more energy you store in the bungee and the higher the model should be lifted unless you make a mess of controlling the climb.

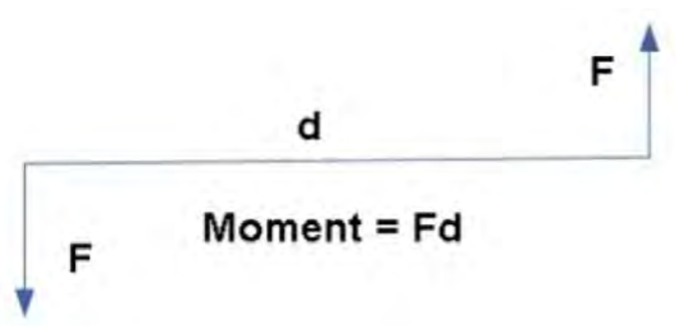
To calculate change of shape we need to know how bendy the object is, called elasticity. The simplest equation here is Hooke's Law, that describes the extension of a springy object with increasing load. So extension is proportional to force or one of two opposing force to be exact.

Hooke's Law: *Extension* = *Force* / *stiffness*

Hooke also said that if you stretch it beyond a certain point called the elastic limit some of the stretch will be permanent. The molecules have been rearranged. That's why when you let a balloon down it doesn't go back to its original size.

Rotation

Two equal and opposite forces cancel each other if they are in line. They can cause rotation if they are not in line, that is if there is a distance between their lines of action. We call this turning effect torque or moment of force. Torque is found by multiplying one force by the perpendicular separation as shown in Picture 10.

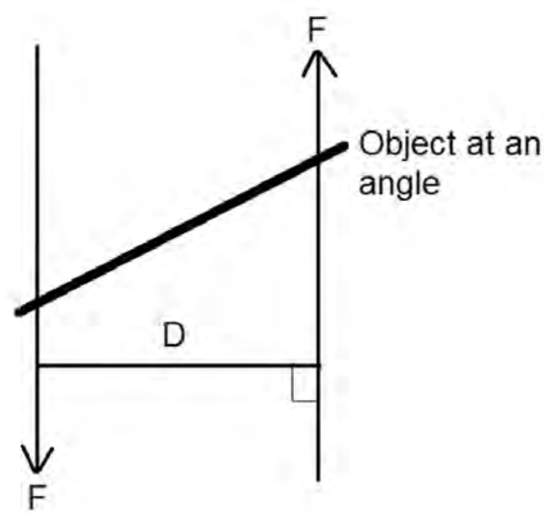


Picture 10

When the second force is well separated from the first we usually call it a moment rather than torque.

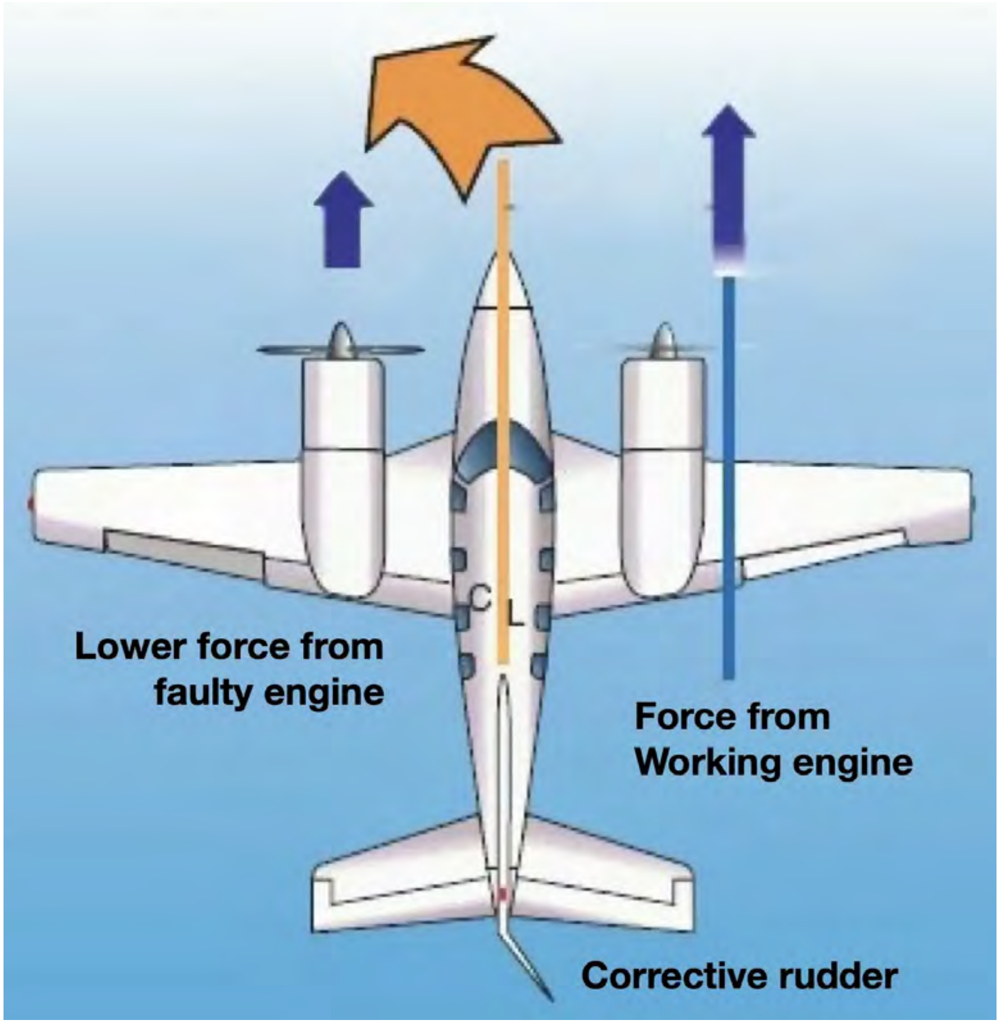
The unit of torque or moment has two parts, a force and a vertical distance apart. Units of measurement that have more than one component are called derived units. In the case of torque the derived unit is metre newton (mN). Actually in a text book you will see this written Nm. I dislike this as it can be confused with work done which is force times distance (Nm). However I give in as it's the accepted way and mN can mean millinewton. In old units this will be foot-pounds or more correctly foot-poundals, where there are 32 poundals of force acting on a pound mass near the earth.

Things are a little more complicated when the two forces are at an angle to the thing they are rotating. Here we have to find their perpendicular separation D not how far apart they are on the object. As shown in Picture 11 $Torque = F \times D$



Picture 11

Another complication is when one accelerating force is larger than the other. What happens in the case in Picture 12 showing a twin engine aircraft where one engine is running poorly and producing less thrust? The forces will rotate the aircraft with a torque based on the difference in the forces. Yaw would result from the difference in moments of the two thrusts about the centre line CL, so needing rudder correction. At the same time the aircraft will move or accelerate based on the sum of the forces.



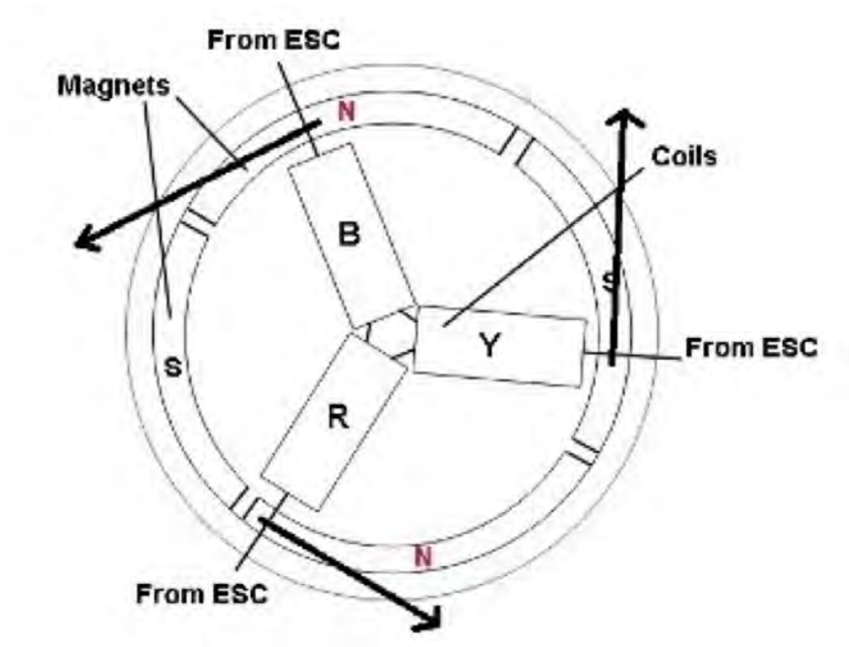
Picture 12 (credit: Adapted from Quora.com)

Examples of Torque in Model Aircraft

Rotational Effect of a Motor and an Engine

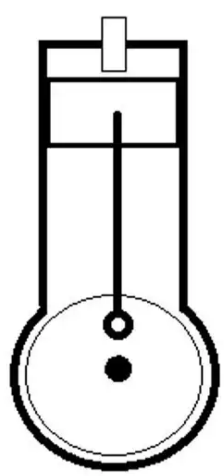
Looking at the geometries of internal combustion (IC) engines and electric motors you can clearly see why the latter are smoother running.

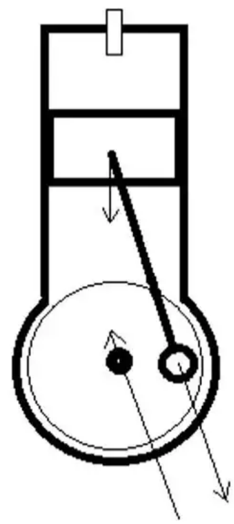
Remember this diagram of an outrunner motor (Picture 13)? I have added dark arrows to show the force from each coil. Notice that they are at a tangent to the motor case. In a practical motor layout with many coils they will also be pretty constant and the case will act as a fly wheel anyway.



Picture 13

On the other hand in Pictures 14 and 15 is an IC engine. The piston moves up and down and the crankshaft rotates. The connecting rod and circular crank web, which was a brilliant Victorian invention, turns the linear motion into rotation, but the force it exerts varies with the angle of the conn rod. So not only are the piston and conn rod continuously reversing direction but the torque produced varies from zero to a maximum. Also the power stroke is only for half the time for a two-stroke engine and a quarter for a four-stroke.





Picture 14 and Picture 15

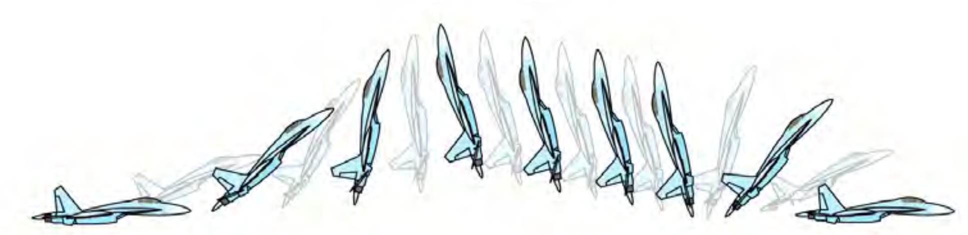
Picture 14 on the left shows the piston at top dead centre. The force down the connecting rod is exactly opposed by the push back from the pin on the crankshaft. There is therefore no torque. In Picture 15 on the right the crankshaft has rotated a bit, initially because its momentum carries it over. There is now a perpendicular distance between the forces from the conn rod and the crankshaft's centre and there is therefore torque. However the connecting rod is at an angle to the piston's force so the component of the force down the conn rod is smaller. You can see that as the engine rotates the torque will vary wildly during the power stroke from a maximum a little before Picture 15 to zero as in Picture 14.

Another inefficiency is that some of the energy generated is used in the compression stroke to squeeze the fuel and air mixture ready for it to catch fire next time. This is one reason why internal combustion engines typically turn about 25 to 30% of the energy in the fuel into useful energy. For electric motors this is around 90%. The reciprocating engine and crank was a brilliant design but things are even better now. I must remember when next at the field not to turn my back on the fellow club members who love their noisy IC engines. 'No, we haven't seen him around today.' 'What spade?'

When at university I attended a lecture on automobile engineering. You won't believe it but then I was a bit of a smart-arse. Foolishly the lecturer invited questions at the end. I said, “Most of a modern car is ancient technology. When do you think there will be a major advance in car design?” Silence. I had in mind Rudolf Diesel (1858–1913), Nicolaus Otto (1832–1891) and Earle S. MacPherson (1891–1960), who would easily recognise the diesel and petrol (gas) engines and the suspension strut used in ‘modern’ cars. Coil springs were invented in 1906 and independent suspension in 1922. Well of course we now know the answer to my question — “When?” It’s now. We now have smooth electric motors and electronically controlled suspension. In the nineteen-sixties NSU had a go at a petrol rotary engine, called epitrichoidal, or less fortunately Wankel, but it wore out quickly, as an aquaintance of mine found out to his cost. 20,000 miles between rebuilds! However it was very smooth and powerful and other car companies have tried it since including Mazda and Chevrolet. If only the batteries were better, and the prices of the cars more sensible, I would love an electric car.

Vectored Thrust

A fellow club member has ducted fan scale models that are always a joy to watch. One special treat is his Sukhoi Su35 *Flanker* with vectored thrust. He has mastered the cobra manoeuvre in which the nose is forced upwards to beyond the vertical followed by falling forwards imitating a striking cobra as you see in Picture 16. When Mark is in the air we give him the sky and all just watch. Once the thrust is vectored to create a moment about the neutral point it pushes the nose up. There is only a small component of it left to push the model forward. The cobra has be entered with plenty of speed.



Picture 16 (credit: Wikimedia)

Servo Torque

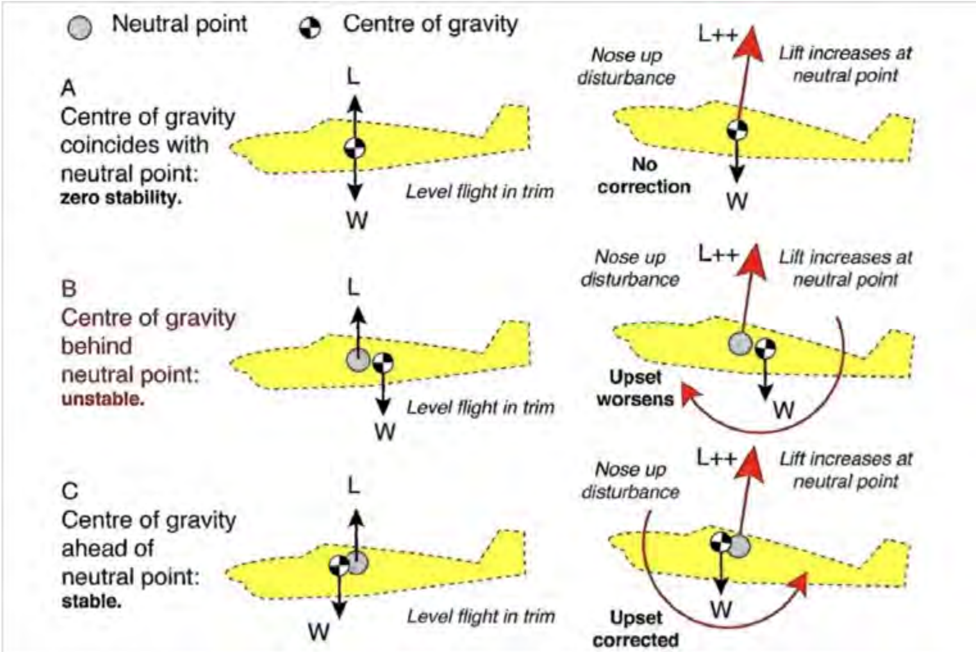
Torque is measured in Nm but the strength of a servo (torque) is usually given in kg cm. This because people know what a kg feels like and a cm is more manageable for things smaller than a metre. How much force a servo produces depends on the length of the servo arm. A 20kg cm servo will make a force of 10kg at the end of a 2cm arm but only 4kg on a 5cm one.

Centre of Gravity, Pitching Moments and Neutral Point

There are two vertical forces on a model aircraft. Weight acts downward and lift acts upward. In level flight they are equal and opposite in magnitude. The weight acts through the centre of gravity (CG) and the lift through the centre of lift (CL) also called Neutral Point. What if the CG and CL are separated horizontally? This will create a turning effect — a torque — that will cause pitching. If the CG is in front of the CL the model will tend to pitch nose down. This makes it stable but unresponsive. If the CG is behind the CL the nose will pitch up and the model will tend to a stall. In this state, provided the pilot can maintain stabilty, the model will fly slower and for gliders this usually means a longer flight. Note the term neutral point is often used in place of CL. This will include lift from the tailplane and fuselage so will be slightly different from CL.

> “**Neutral point** is a **point** around which the pitching moment does not change with angle of attack (a.k.a aerodynamic centre; **neutral point** is usually that of the whole **aircraft**, aerodynamic centre of individual airfoils).” — *aviation.stackexchange.com*

This excellent Picture 17 from Martin Simons’ superb book *Model Aircraft Aerodynamics* explains it better than I can. You can read more in my article on Martin’s three books.



Picture 17 (credit: Martin Simons with permission)

Thrust Lines and Neutral Point

Motors are nearly always set at a slight angle right and down. Only a few degrees. The idea is that the thrust (force) vector should go through the neutral point. If it does the thrust produces no moment of force so a change in throttle won't cause yaw or pitching. Of course in the case of propellors it is more complicated. There is a torque opposite to propellor rotation and other effects that cannot be cancelled by thrust line adjustments for all throttle settings.

Tailplane Upforce and Stability

A tailplane stabilises a model automatically. That is why it is sometimes called a horizontal stabiliser. I dislike the latter as it exhibits verbal diarrhoea with eight syllables where the word tailplane is short with two and tells you exactly what it is. We all know that a model with a small tailplane on a short fuselage is less inherently stable so needing a more forward centre of gravity. The small tailplane generates a smaller force and the shorter tail boom gives a shorter distance for it to act, so the restoring torque or moment is less. Similarly a long boom will strengthen the moment of the elevator. A glider can tolerate a tiny tailplane if the boom is long as is the case with my ASW.

Inertia

Mass opposes change in velocity. It is one the fundamental laws of the universe that ‘the universe fights back’. Starting in 1884 Le Chatelier devised a law, initially for chemical reactions but later applying it to all changing systems, that whenever something external to a physical system causes a change the system will oppose the change. In the case of objects being speeded by a force the mass of the object opposes the force. We call this inertia. Newton described the two forces as action and reaction. In the case of an accelerating thrust he wrote the equation for his second law $F = m \times a$.

When we speed up a model the inertia of the mass of the model will try to stop us. When we increase the current in our motor wires the resulting changing magnetic field induces a ‘back EMF’ in the wire that opposes the applied voltage. Both are reactions.

We use the same word, ‘reaction’, in the field of human behaviour. People who habitually oppose change in their communities are called reactionary. That is not always negative. I like the ironic phrase, ‘The Power of Negative Thinking’, meaning that people who are critical are of great value in testing new ideas. I learn a lot from justifying new technologies to the reactionary old guard on the flying field.

> **Henry Louis Le Chatelier**
>
> Henry Louis Le Chatelier was born on 8 October 1850 in Paris and was the son of an influential French materials engineer Louis Le Chatelier and Louise Durand. His mother raised the children strictly. As he said, “I was accustomed to a very strict discipline: it was necessary to wake up on time, to prepare for your duties and lessons, to eat everything on your plate, etc. All my life I maintained respect for order and law. Order is one of the most perfect forms of civilization.”

As a child, Le Chatelier attended school in Paris. At the age of 19, after only one year of instruction in specialized engineering, he followed in his father's footsteps by enrolling in the École Polytechnique in1869. Like all pupils of the Polytechnique, in September 1870 Le Chatelier was named second lieutenant and later took part in the Siege of Paris. After brilliant successes in his technical schooling, he entered the School of Mining in Paris in 1871.

Despite his interests in industrial problems, Le Chatelier chose to teach chemistry rather than pursue a career in industry. He taught at the Sorbonne university in Paris.

He is best known for his work on his principle of chemical equilibrium. He also also carried out extensive research on metallurgy and was a consulting engineer for a cement company, today known as Lafarge Cement. His work on the combustion of a mixture of oxygen and acetylene in equal parts rendered a flame of more than 3000 degrees celsius and led to the birth of the oxyacetylene industry.

One thing passed him by. In 1901 he combined nitrogen and hydrogen at a pressure of 200 atmospheres and 600 °C in the presence of metallic iron — a catalyst. An explosion occurred which nearly killed an assistant. Thus it was left for Fritz Haber to develop and, less than five years later, Haber was successful in producing ammonia on a commercial scale, used both for explosives and fertilisers. Remember the huge explosion in Beirut harbour in 2020? He wrote, "I let the discovery of the ammonia synthesis slip through my hands. It was the greatest blunder of my scientific career". One rather worrying fact I have learned recently is that fertiliser production results in huge quantities of carbon dioxide being produced, roughly 1% of the world's greenhouse gas each year. I only learned that because fizzy drinks (soda) were in short supply in 2022 as fertiliser production dropped due the war in Ukraine.

> Incidentally Haber's work on chemical warfare and explosives deserves a grim read. The First World War would have ended far sooner without Haber. His wife shot and killed herself probably due to Fritz's war work. — *(mostly) Wikipedia*

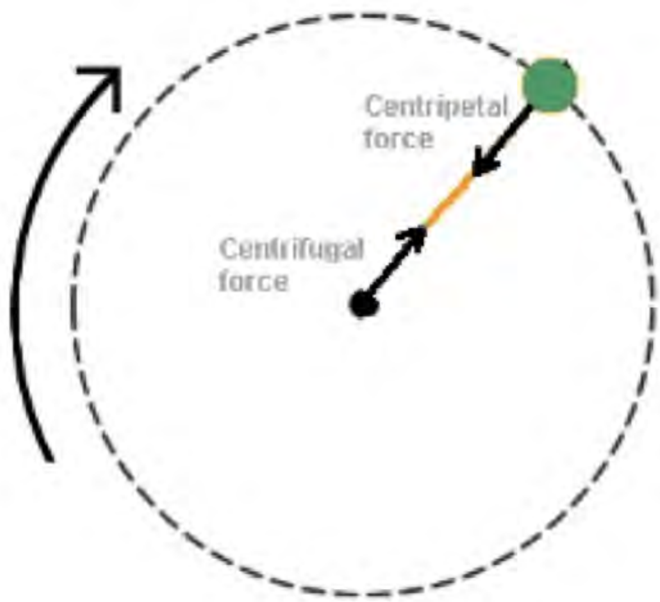
Negative and Positive Feedback

In negative feedback the reaction opposes the change. When you try to push something the friction forces oppose you. The opposite, positive feedback, can be very dangerous in our field. This is where the reaction adds to the change. Imagine if friction was reversed. As soon as you start pushing, the object would accelerate away without stopping.

Suppose you had reversed the movement on your ailerons. Yes I have done that! You? You can take off straight but, as soon as you try to bank, the ailerons bank you the wrong way. So you automatically apply more stick which would normally oppose the bank but in this case makes the problem worse. Crunch! A gambler who is losing, instead of stopping can convince himself that another bigger bet will get his money back. Bang goes the house. Many believe that the speed at which automated trading systems work increases the instability of the market. People are selling, so the system does more selling in microseconds. Positive feedback. Prices plummet. That happened in London just after the 'Big Bang' of 1987.

Dynamic Forces

Dynamic forces either cause a change in motion or result from it. One example is centrifugal and centripetal forces, shown in Picture 18, which are oft misunderstood. When you twirl a ball on a string your hand feels the ball pulling on you through the string. This is the centrifugal (inertial) force. What the ball feels from you through the string is centripetal force, which is what makes it circle. Let the string go and the ball initially flies in a straight line tangential to the circle as the centripetal force drops to zero.



Picture 18

Newton's Third Law can also be worded 'nature fights back'. If you impose a force on something it pushes back on you with an equal and opposite force.The string experiences both as a stretching tension force.

Experiment One: Inertia

This could be a thought experiment or, with care, done practically. Find a weight onto which you can tie a string. Ideally it should be a few hundred grams but softish so it does not damage you or anything else when it falls. Some lead shot or baking pellets in a bag would work.

Find a piece of fairly weak string but strong enough just to hold the weight. Cut off about a metre. Tie it to something solid, then tie the weight in the middle. You will pull at the bottom of the string. For the first time gradually increase the pull until the string breaks. Where will it break? Yes of course, it will be above the weight because your pull adds to the weight so is greatest above the weight. Now retie the string. This time snatch hard at the bottom. What happens? The string breaks below the weight. It didn't? Do it again and snatch harder. This time the inertia of the mass of the weight gives a large inertial force that does not reach the upper part of the string.

Degrees of Freedom

There are three linear degrees — forward, down and sideways — and three rotational ones on the same axes. Our models have all six. They are the pleasure and scourge of model flyers. When we get it right it is a delight. Wrong and we pick up the pieces. Cars or boats have fewer degrees of freedom. Model railways even fewer.

To sum up:

- a single resultant force causes movement change in one or more linear degrees
- a pair of identical but opposite forces with a gap between them causes change in one or more rotational degrees.
- a pair of different forces with a gap between them causes change in all degrees.

Pressure

How can a performer lie down on a bed of nails without harm? Why do stiletto heels make holes in floors? How can a small force on a bicycle tyre pump make the tyres really hard? Why do elephants have such wide legs? Why do snow shoes work? The answer is pressure. When a force is spread out over a large area it is less destructive.

Pressure = *force* / *area*

The SI unit is the pascal Pa. This is one newton per square metre (N/m^2), which is a small amount. The result is that practical pressures work out to hundreds of thousands of pascals. Your car tyres will be a bit more than 200,000 Pa (200 kPa). This is one of the few SI units that really is a nuisance, so we often use the bar, which is 100,000 Pa — the average pressure of the atmosphere near the ground. In old units this will be about 14 psi (pounds per square inch).

> **Blaise Pascal (1623–1662)**
>
> Pascal was a polymath, working in the fields of mathematics, physics, mechanical inventions, philosophy and catholic theology. He was a child genius, educated at home by his father, a tax collector in Rouen. He was a strong proponent of the scientific method. He worked with Fermat on probability, influencing economics and social science. He invented one of the first mechanical calculators, called the Pascaline, and a hydraulic press. We know him for his work on fluid dynamics, pressure and vacua, so the SI unit of pressure, the pascal (Pa), is named after him. He always suffered poor health, not helped by living a very austere, ascetic life style stimulated by his belief that humans should suffer. The cause of his early death is uncertain but tuberculosis or stomach cancer are thought likely. I also wonder if he was affected by the mercury that sloshed around when he was experimenting with barometers. — *(mostly) Wikipedia*

Why We Only Need a Tiny Pressure Change for Lift

This is from a previous article in the New RCSD. We are at the bottom of a roughly 20km deep sea of air. At sea level the forces from the air particles are high, though our bodies are adapted to it so we don't notice it. A cubic metre of air has a mass of about 1kg. So a one square metre column of air 20km high has a mass of 10,000 kg assuming the density steadily drops to zero. So each square metre has a pressure of about 100,000 pascals on it due to this air piled up on top of it. Each pascal is a newton per square metre. A newton (N) is the weight of a 100g medium apple (nice!). A kilogram weighs ten newtons. So each square metre has 100,000 apples on it or 10,000 kg as suggested above. You can see that you only need a small change in this to create a large force. To generate a lift force of 1kg (10N) on a surface area of one square metre you only need a pressure difference between the upper and lower surfaces of 10/100,000 or a hundredth of one percent. A 5kg model with a wing area of 0.5 m^2 will only need a 0.1% difference.

Yes, that surprised me and I had to check the data for that percentage figure again when I calculated it. I also tried again in older units where atmospheric pressure is 14 lb/square inch. There are 1,550 square inches in a square metre. So there are 1,550 x 14 or about 22,000lb force. There are 2.2lb in a kg so the answer is again about 10,000 kg and 100,000N. Phew!

Friction

Even the smoothest pair of surfaces is rough at the microscopic level. For a highly polished surface the roughness peak to trough will be around 2 um (micrometres). Both surfaces will have that roughness and will settle into each other when stationary, making it more difficult to get them sliding.

As you can't make anything really smooth the only way significantly to reduce friction between two solid things is to keep the two surfaces apart. In any case if you could create two really flat surfaces, perhaps a single layer of atoms such as graphene, the two would stick due to different types of force that are outside our article.

The study of how you keep surfaces apart is called tribology — separating them with liquids, powders, air cushions or magnetic fields. Liquid lubricant molecules are often long and have ends that attach to surfaces. They line up like the bristles of a brush to hold the surfaces apart. The alternative is to make the surfaces from materials that are naturally slippery like Teflon (FTFE). I use a pair of tiny PTFE washers on my indoor model prop shafts for rubber motors. I make them from a thin PTFE sheet in which I drill holes 1 mm or smaller. I then punch them out using a 2.5 or 3 mm leather punch.

Experiment Two: Friction

As you saw earlier the steeper the slope the greater is the component of weight pulling an object down the slope. The extremes are zero when horizontal and 100% when vertical. A very neat and fun experiment is to get a longish piece of wood, that does not have a high polish, to form a slope. You also need a block of wood or plastic, a protractor and some lubricants, for example water, cooking oil, car oil and talcum powder. You will no doubt think of others. Put the block on the slope and gradually raise one end until the block slides. You could gently tap the slope to unlock the two surfaces. Measure the angle.

Then try it for different lubricants. You could also pin other surfaces to the slope like a polythene bag, some PTFE sheet, a flat piece of glass and so on. The differences in slope should be striking. Even more so would be to use round rods or pencils as rollers. Using rollers or wheels means there is no sliding friction as the point of contact doesn't slip. That is how ball and roller bearings work. You can find the friction force as it is equal to mg sinθ. We compare frictions for two surfaces by finding coefficient of friction.

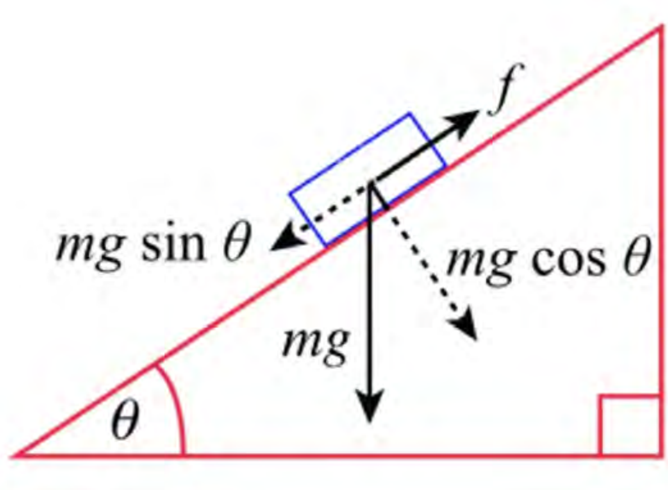
Coefficient of friction μ is the friction force (static or dynamic) divided by the force pushing the surfaces together.

$\mu = \textit{friction force} / \textit{pressing force}$

Now we look at the more complicated slope diagram in Picture 19 at the point of sliding.

Friction force f (equals the component of weight down the slope) = $m \times g \times \sin\theta$

Force pushing the surfaces together (component of weight into the slope) = $m \times g \times \cos\theta$.



Picture 19 (credit: Wikipedia)

You can find the coefficient of friction μ ('mu') from:

$\mu = m \times g \times \sin\theta \,/\, m \times g \times \cos\theta = \tan\theta$ as $\tan\theta = \sin\theta \,/\, \cos\theta$

A slope angle of 45º give a tangent value and μ of 1. Most materials will slide at much lower angles. Typical values from wikipedia are:

Brass on steel 0.35–0.51 19º — 27º e.g. bearings

Glass on glass 0.9–1 42º to 45º surprising

Steel on 'ice' 0.03 1.7º e.g. skating

PTFE on PTFE 0.04 2.3º e.g. my indoor models

PTFE on steel 0.04 to 0.2 11.3º e.g. PTFE bearings

Static and Dynamic Friction

If you do the experiment you will find that the angle and friction force is larger just before the block starts to slip as mentioned above. This is because the roughnesses of the two surfaces have settled into each other and need an initial lift. OK, that's not wonderful science but it gives you the idea. The initial friction is called static friction. When moving it is called dynamic friction. To measure that you need to give the block a slight shove, or the slope a tap, to get the block started.

Ice Skating on Water

No-one skates on ice. The pressure produced by a narrow skate blade melts the ice so the skater rides on a layer of water, and the friction then drops as the skate and the ice are separated by the water. This is only true down to about -30ºC when a human body can't produce enough pressure to melt the ice. Does this mean that a light model with wide skis might feel greater friction? Anyone know? I don't fly from snow.

That's it for this part. Next month I'll be talking about energy. Thanks for reading and we'll see you next time.

Resources

- *Peter Scott* — The contact page on the author's personal website.
- *Rediscovering Martin Simons* — By happy coincidence, the author is already currently curating a series on Martin Simons' books. In Part IV, which appeared in the November 2022 issue of the *New RCSD*, the study of Martin's model aircraft-related books commenced.
- *Institute of Aerospace Engineering, Brno University of Technology* — The organization which provided the key photo — which appears above the title — for this article. We thank them for permitting it's use and in particular Associate Professor Dr. Jaroslav Juračka for his assistance.

Also by the Author

- *Electricity for Model Flyers* — The author's complete, highly regarded series presented on the pages of the *New RC Soaring Digest*.
- *Cellmeter 8* — "What's on offer for this economical battery meter and servo tester? Quite a bit, actually…"

- *The Fine Art of Planking* — “The time-tested method for moulding strips of wood into an organic, monocoque structure…”

All images are by the author unless otherwise noted. Read the ***next article*** *in this issue, return to the* ***previous article*** *in this issue or go to the* ***table of contents****. A PDF version of this article, or the entire issue, is available* ***upon request****.*

1

Soaring the Sky Podcast

The Perlan at altitude. (credit: The Perlan Project, Inc. / Airbus)

E092: The Perlan Project, Soaring On Mars and the Club Class Nationals

Our seventh instalment of this ongoing series where we select and present episodes from Chuck Fulton's highly regarded soaring podcast. See Resources*, below, for links where you can find* Soaring the Sky*, or simply click the green play button below to start listening. — Ed.*

On this episode, we first talk with Miguel A. Iturmendi-Copado, one of the pilots from the *Perlan Project* as he answers your questions and shares his adventures flying super high altitudes and what it's like soaring in the only pressurized glider in the world. Is it possible to fly the *Perlan* on Mars? You may be surprised when you hear the answer. Miguel is also a test pilot and will also tell us about a very famous solar motor glider he has been flying most recently.

Also, at 52:52, Dale Masters is back and has another *Soaring Tales With Dale* and this one is titled *Eagle Eyes*.

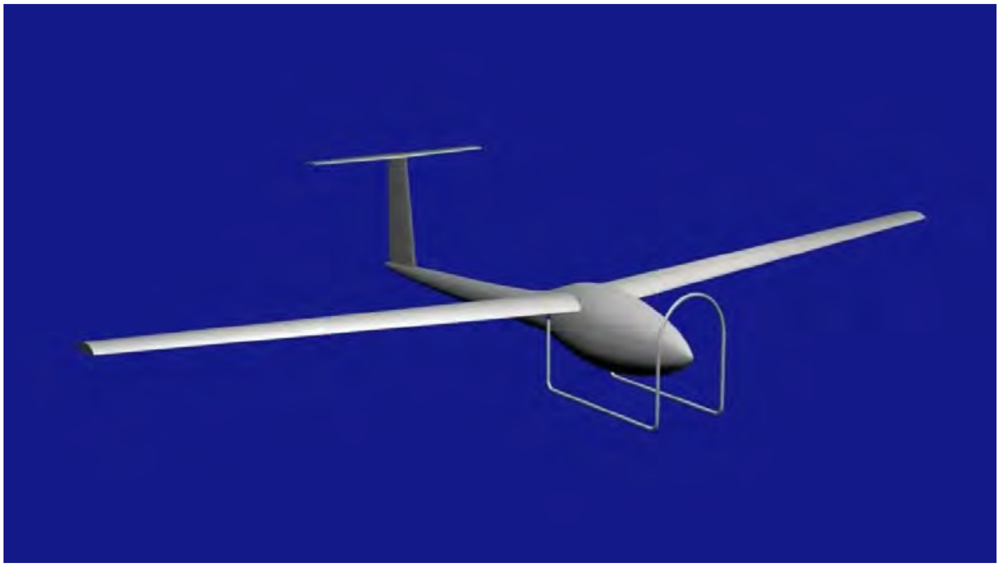
Finally, at 56:58, contestants David Hart and Daniel Sazhin chat with us on location at Chilhowee Gliderport (92A) in Benton, Tennessee as they get ready to compete with others in the Club Class Nationals! What is it like flying a contest? How is the course? All this and more now on episode 092 of *Soaring The Sky*!

Resources

- ***The Perlan Project, Inc.*** — From the website: "The Perlan Project is an internationally celebrated, world record setting climate and aerospace research project…"
- ***Soaring the Sky*** — From the website: "an aviation podcast all about the adventures of flying sailplanes. Join host Chuck Fulton as he talks with other aviators around the globe". You can also find Chuck's podcast on Instagram, Facebook and Twitter

Subscribe to the Soaring the Sky *podcast on these preferred distribution services*:

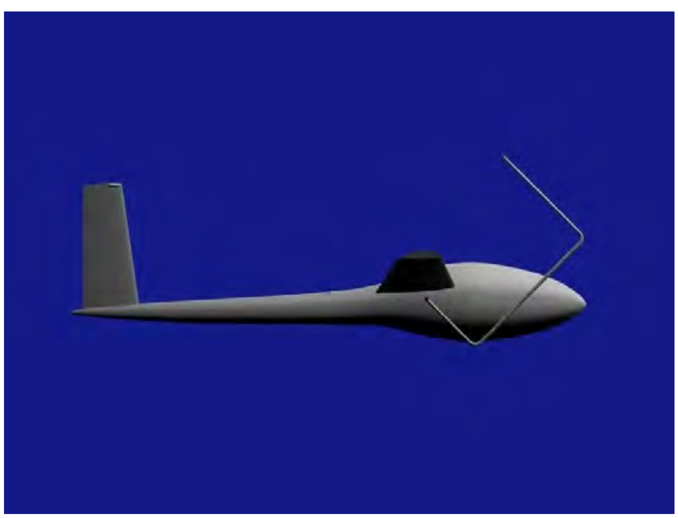
CG Balancer for Large Scale Sailplanes

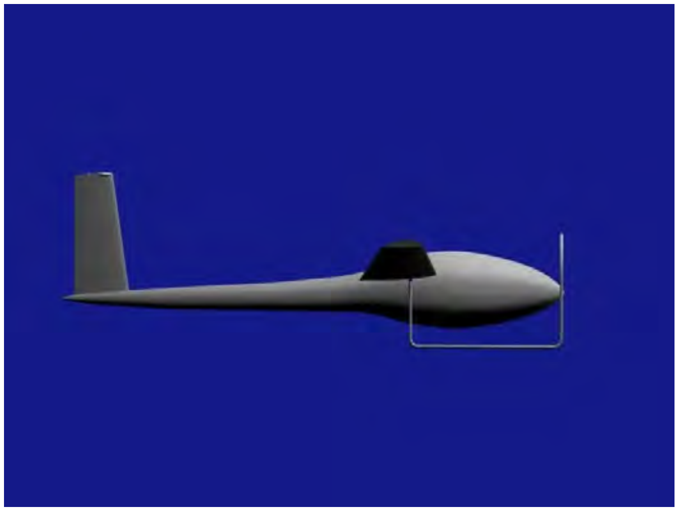


The positioning of the balancer while balancing is in progress.

So simple (yet effective) it almost explains itself.

I was always having trouble balancing my large planes. It seemed I needed two people to assist me. They would have to crawl under the wing and hold up the plane. It wasn't very accurate and I wanted something I could use by myself. Here's the simple center of gravity (CG) balancer for large scale planes that I came up with.





Left: Place under plane, as shown. | Right: Push the U-shaped handle down to lever the plane up.

Place under plane and push down. Lets you lift the plane from ground, rather than having to lift the plane by hand and set it on something. I used 1/2" aluminum rod, but you can use a pipe and ‘T’ rig also.

Works great!

The Year of 1911 in Aviation … and the Wright Glider

"Three-quarter left rear view of glider in flight at Kitty Hawk, North Carolina" in October of 1911. (credit: Wright Brothers Papers, Library of Congress.Library of Congress)

A look back at a momentous year which included the further development of soaring as a recreational pursuit.

This article originally appeared in the February, 2012 issue of no-longer-published WW1 Aero: The Journal of the Early Aeroplane *and appears here with the kind assistance of Jonathan Fallon, the former editor of the publication. Also, click on any image for a larger version. — Ed.*

Progress in the science of aviation in 1911 surpassed any twelve months' advancement recorded since the Wrights first flew in a motor-driven airplane in 1903. These advances were not confined to a particular country or continent, since every section of the world was now taking part in aviation history-making. The editors of the 1911

World Almanac estimated that more than 3,000 miles have been covered in aeroplane flights and more than 7,000 persons, either as aviators or passengers, took into the air during 1911.

Flying had passed from sensational exhibitions for the curiosity of the crowds to the realm of accepted fact. Death, disaster and new enterprise were rife and the impartial spectator found it at times difficult, if not impossible, to arrive at an accurate measure of the net progress made. The United States was slowly losing its lead in aviation, as seen in the table below, which appeared in *Flying, Fast and Furious*, by August Post in *The World's Work*, July 1911 (see link in *Resources*, below).

to be made over the English Channel between the ports of Calais, Dover, Folkestone, and Boulogne. In fact, a man may fly in almost any direction from any point he chooses and compete for a prize.

AVIATORS HERE AND ABROAD

COUNTRY	NUMBER OF LICENSED AVIATORS
France	339
Germany	43
England	39
Italy	27
Belgium	24
America	18
Austria	18
Switzerland	3
Denmark	3
Spain	2

In this country the flights, with certain brilliant exceptions, have not been as spectacular as those abroad and yet last summer saw a flight from Albany to New York, another from New York to Philadelphia, a third from Key West almost to Cuba, a fourth from Los Angeles to the

States is as advanced as any country, for there is a large prize awaiting the winner of the San Francisco-New York race (less than ten years after the first transcontinental automobile journey) and another for the winner of the trip between St. Louis and New York. There is also an "American Circuit" to include Indianapolis, Chicago, and St. Louis.

So far a million dollars has been won by aviators. This year should add another million to their earnings.

Less dramatic than the increases in the altitude and speed records, less dramatic than the trans-alpine and cross-channel flights and yet, in a way, more important to the development of the science of flying, is the turn which the inventors and builders of machines are taking. The vast amounts of money, of energy, and of brain work that have been, in the past, largely dissipated by thousands of inventors in widely divergent channels are now being concentrated

Clipping from 'Flying, Fast and Furious' by August Post in 'The World's Work' published in July, 1911.

Aviators (or pilots) tried to bring greater honors back to America with daring feats — only to lose their lives. Throughout 1911, newspapers and magazines described with colorful headlines *The Toll of Lives the Air has Taken* and all the *Fatalities of Flight*. On October 15, 1911, the *New York Times* was just one newspaper that gave on page one the news that *Aviation Victims Now Number 100* (see clipping in *Resources*). People were killed either flying an airplane or standing on the ground. The causes of these flying accidents, many with Wright airplanes, were not completely understood, but it was generally believed that stability and control were the pressing problems of save human flight.

NEW-YORK DAILY TRIBUNE. SUNDAY. JANUARY 22. 1911.

Aviators Not at All Dismayed by Toll of Lives the Air Has Taken

Ten Times as Many Airmen Killed Last Year as in 1909, but Total Distance Flown in 1910 was Twenty Times as Great as in Previous Twelve Months.

Experts Deny That Faulty Construction of Aeroplanes Is Responsible for Fatalities, but Believe Safer Method of Control Will Be Found.

TENNYSON'S "GHASTLY DEW."

From the 'New York Tribune' published on January 22, 1911 (see 'Resources').

Mechanical flight was an accomplished fact and a success, but stability in flight had to be assured. When an aeroplane is stable, it has the power of preserving the natural level in flight — or its equilibrium. If this equilibrium is upset by a sudden gust or in turning, the aeroplane should be capable of regaining its natural level with a minimum of oscillation. This detail was behind every tragedy that had shocked the world of aviation during 1911.

The more than two hundred different types of aeroplanes in use worldwide included ever-improving versions of tried machines, with new machines coming from both famous and unknown manufacturers. They ranged from monoplane to biplane, triplane and even quadraplane designs. The monoplane, whose possibilities were hardly recognized in earlier days, provided speed and efficiency; it now rivaled, if not surpassed, the older biplane so successfully used by the Wright brothers in the United States and various enthusiasts in France.

Extracted verbatim from *1911 World Almanac, Aviation:*

> Two of the prominent developments of 1911 were the introduction of the hydro-aeroplane and the motorless glider experiments of the Wright brothers at Kill Devil Hills, N.C, where during the course of two weeks experiments numerous flights with and against the wind were made, culminating in the establishment of a record of Orville Wright on October 25, 1911, when in a 52-mile per hour blow he reached an elevation of 225 feet and remained in the air 10 minutes and 34 seconds. The search for the secret of automatic stability still continues, and though some remarkable progress has been made the solution has not yet been reached.

It should be noted that Orville set his record on 24 October, 1911 and that he remained in the air for 9 minutes 45 seconds.

The two players: Orville Wright (left) and Alec Ogilvie. (credit: Wright Brothers National Memorial Collection)

Orville Wright, brother Lorin, nephew Horace and Alec Ogilvie from Great Britain spent a little over two weeks at Kitty Hawk, combining business with pleasure. Orville had stated earlier that “flight without the use of a motor” was the most perfect form of flying. Being in need of a vacation he wanted to have fun flying, but also experiment and hopefully make some “startling discoveries” in regard to stability and control of their aircraft. During this time the glider was constantly redesigned, and after a lot of trial and error — mostly trying to establish the correct location of the “Center of Pressure” while the “Center of Gravity” was not part of the discussion — Alec soared for almost five minutes on October 17 and Orville remained airborne in ridge lift for almost 10 minutes on October 24.

Parts from several airplanes, readily available at the Wright factory, were used to create the new Wright 'Soaring Machine'. Above: The Wright Model B was the first Wright aeroplane manufactured in quantity, and incorporated several new features that departed from previous Wright designs, including wheels and an aft mounted elevator. (credit: Wright State University Libraries)

The Wright Model R, 'Baby Grand' was designed for speed, and featured a reduced wingspan and an eight cylinder engine that generated roughly 60 hp. It was hoped that the Baby Grand would win the Gordon Bennett trophy in 1910, however, the aircraft suffered substantial damage after an engine failure and was unable to participate in the race. (credit: Wright State University Libraries)

Newspaper write-ups were plentiful and offered colorful headlines, but they are of somewhat questionable value. The personal diaries of Orville Wright (1911 Diary V, Wright Papers, Library of Congress and marked as O.W.) and of Alexander Ogilvie (extracted from the article *Golden Jubilee of Soaring* which appeared in the journal *Sailplane and Gliding* of December, 1961 and marked as A.O.) gave the best factual information, and appear below combined into one story.

Oct. 7. (A.O.) — Glider 145 lbs, crated and shipped. [Took] 6.0 train for Kitty Hawk via Cincinnati, Norfolk, Elizabeth City with Orville, Lorin and Buster, on 9.30 Chesapeake and Ohio Pullman.

Oct. 9. (A.O.) — Shopped in morning. On board Hattie — Captain Johnson 12.45. Arrived Manteo 6.15 p.m. Stopped Tranquil House. Mrs. Evans. Harwood of the World called after dinner to see O.W.

The Tranquil House Inn, Manteo. (credit: Photo: Drinkwater Collection, Joyner Library)

Oct. 10. (A.O.) — By motor boat to Kill Devil Camp, 1hr. 5 mins and then ½-hr. walk. Making latrine, shelves, pump trough, partitions. Rain in night. Warm.

Oct. 11. (A.O.) — Cloudy and warm. Making ladder, bath arrangements, fixing beds in roof. Opened up all 1905 and '08 machines in box. Lorin to Manteo in motor boat. 10–12 m. breeze in afternoon. Sally (reporter) and Harwood. Rain in night.

Oct. 12. (O.W.) — Measured West Hill = 80 ft. high. [Slope] 500 ft. Kill Devil Hill = [Slope] 665 [ft. at] 8° 40' = 103 ft. high. 30-mile wind at top hill. 18 on ground. **(A.O.)** — West Hill. 500 sin 90° 40' — 84 ft. Kill Devil Hill 655 sin 8° 40' = 103 ft. Angle of hills from building K.D. 12 ½° West 8 ½°. [Added subsequently: These data were measured by me with my pocket theodolite. A.O.]

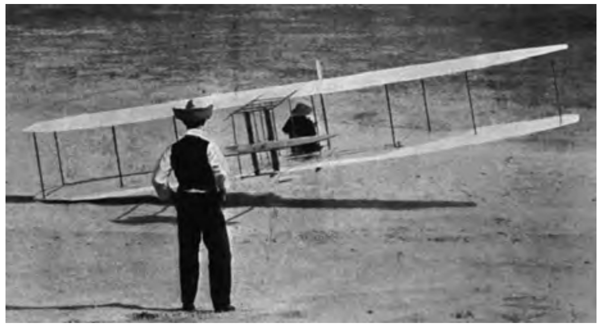
Orville measures slope of hill with a pocket theodolite. This photo originally appeared in the December 1911 Popular Mechanics article entitled "The Secret Experiments of the Wright Brothers," by Victor Lougheed.

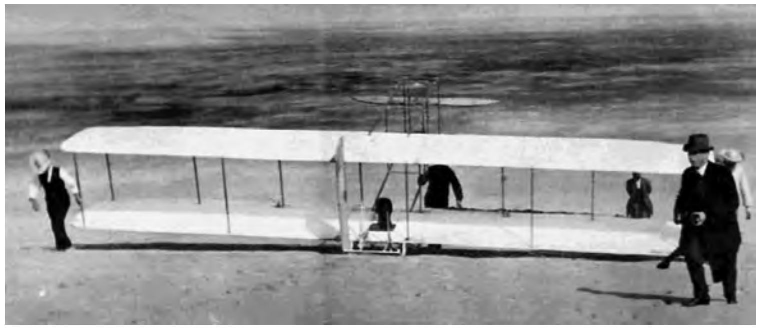
Oct. 13. (O.W.) — Wind north 20–25 miles. Motored to Kitty Hawk through outside channel. Machine arrived on Van Dusen (Shipped Sat. 7th). 4 newspapermen — J. Mitchell, Asso. Press, Mitchell, N.Y. Herald, Sally of Norfolk, Van Ness, New York World, arrived.

The crates containing the glider parts were delivered by horse- drawn carriage (credit: Wright State University Libraries)

Oct. 14 (A.O.) — 10 m. N. wind. Erecting machine in morning. Kitty Hawk in motor boat in afternoon. Buying fish and chickens. Made chicken coop.

Oct. 15 (A.O.) — 3 to 4 m. N.E. wind…



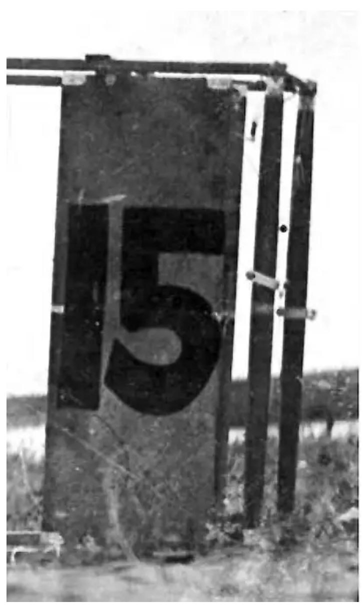


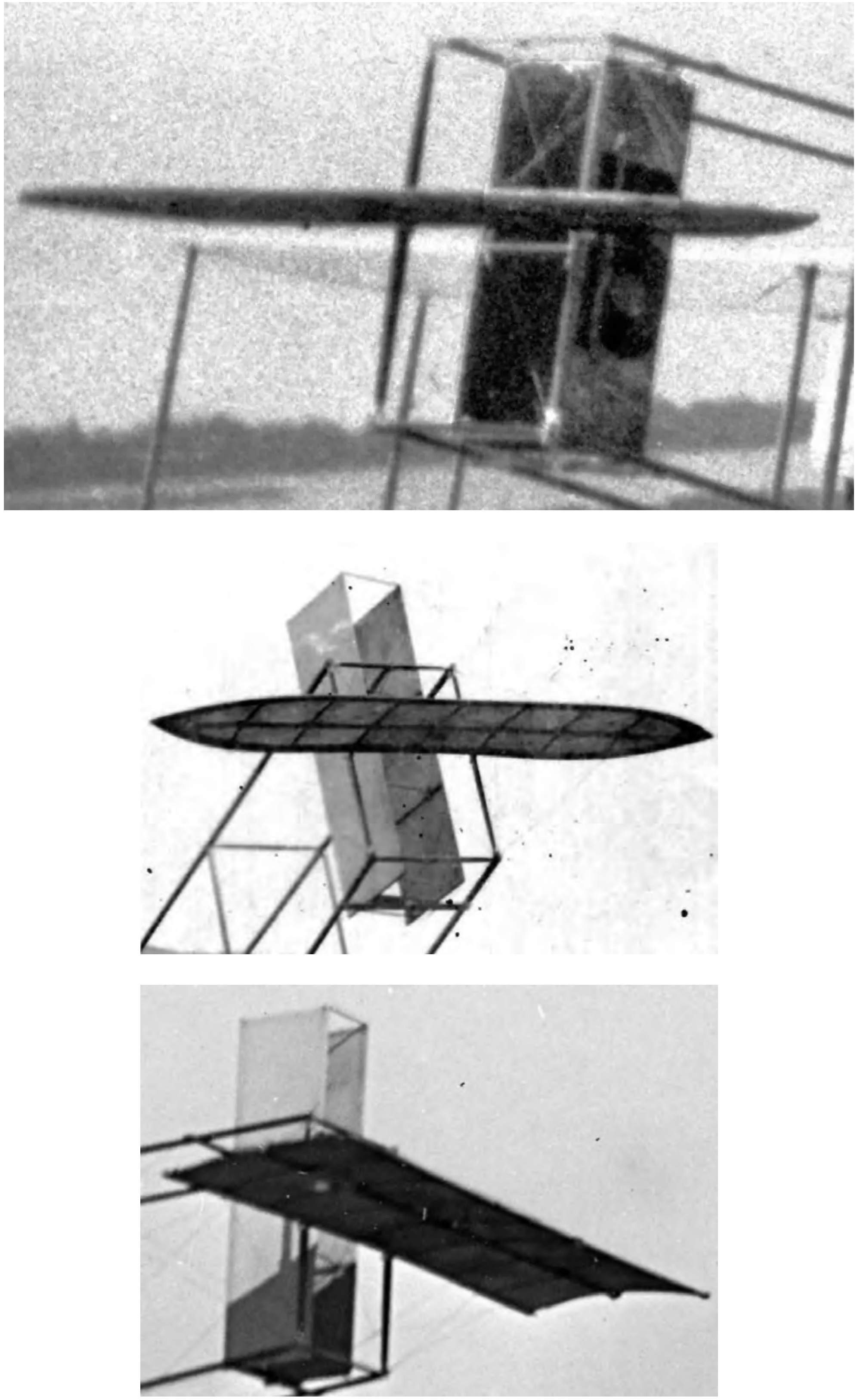
Left: The glider was assembled with the hope to "remain aloft for hours like the soaring birds." (credit: Illustrated London News, November 4, 1911) | Right: New York World reporter Van Ness Harwood was detailed to the Outer Banks to report on the gliding experiments. His papers and photos are housed at East Carolina University's Joyner Library.

Oct. 16 (O.W.) — 12–14 miles from N.E. West Hill: 3 glides. Shot up at landing and dropped about 6 feet, bending rear center uprights. Horizontal rudder too small. Vert. rudder too small (7 ½ ft. area, 7 ft. in rear of back edge of surface). Put on a vane on front upright. Vane was one of the rear rudder planes of 1905 machine, 18" X 6'. Kill Devil Hill: After one glide, in which I pitched forward out of the machine, put on a larger rudder, 38" X 8' 10", using center of 1905 rudder. Afterward made glide of 637 ft. in curved line [plus] 586 ft. in straight line. Angle 7° 45'. Wind very light (4 mi.). Time 23 seconds. **(A.O.)** — Rear elevator too small. One bad thump, bending back centre uprights. Vertical rudder not very effective, better after fixing vane in front. Took glider to Kill Devil Hill. Glide by O.W. Landed on hummock and was chucked out . . . Put on a new tail surface.

The rear rudder of the 1905/1908 machine was pulled from the wrecked camp building and used as a "stabilizing vane" as Alec had seen used in France. The camp is seen here in 1908, after repairs were made to the living quarters in the background. (credit: Wright Brothers Papers, Library of Congress)

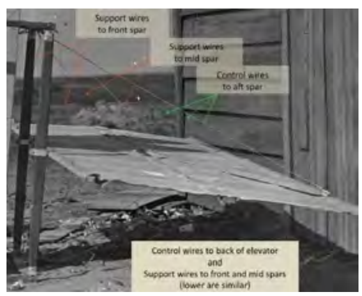
Oct. 17 (O.W.) — Wind 10 mi. southeast. Glides on West Hill. Ogilvie glides 7° 35', 473 ft. Ogilvie 3 glides. O.W. 2.





Detail of the structural modifications made to the tail of the 1911 glider. The original configuration was a good start, but the structure had to be refined and improved to increase its performance to “go into the clouds and soar indefinitely”. In a step-by-step process, just as the brothers did a decade earlier, the aircraft became safer and better performing.

Oct. 18 (O.W.) — Wind 20–25 [M.P.H.]. Rain. Ogilvie wind vane corresponds with our Richard [anemometer] when miles per hour is taken at double meters per second. Took machine out about four o'clock. Front vane 2 ft. from front edge on sliding sticks. Made several glides. In last one, machine turned around in spite of all I could do and ran into hill, turning over. Broke both left wings and rear horizontal surface. John Mitchell present. **(A.O.)** — Raining and blowing 20–25 m.p.h. Cleared up about 4. On Big Hill. O.W. soared three or four times, twice for 1 ¼ min. Vertical rudder 7 ½ sq. ft. at back, 10 ft. from C.P. not big enough. Front vane 9 sq. ft. at 4 ft. from C.P. Machine turned round by the wind and drove into hill. O.W. thrown out unhurt. Left wings broken and rear surface. Over 35 m.p.h. on crest.



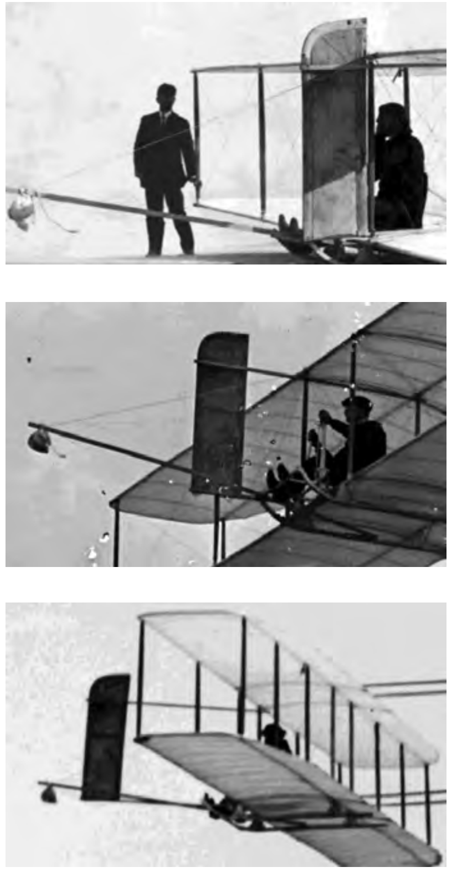
Left: An interpretation of the 1911 glider's tail structure by Neal Pfeiffer of Wichita, Kansas. | Centre: Carrying the glider back up for another launch. (credit: Wright State University) | Right: Another good launch and now soaring. (credit: Wright Brothers Papers, Library of Congress)

Oct. 19 (O.W.) — Wind 20 miles. Busy repairing on wings.

Oct. 20 (O.W.) — Extended tail frame 4 ½ feet. Used small racer horizontal rudder of 15 ½ ft. area projecting above frame. Arnold Kruckman & Berges arrive — N.Y. Amer’n.

Left: The ‘wind vane’. | Right: The Richard Anemometer that Octave Chanute gave to the brothers in 1903. (credit: Chanute Papers, University of Chicago Library)

Oct. 21 (A.O.) — Almost calm. Making new rudder 5 ft. 2 in. high by 1 ft. 6 in. = 15 ½ sq. ft. at 14 ft. from C.P. Fixing old tail surface 14 sq. ft. and increasing range of action.



Changing the position of the ‘front vane’ in a step-by-step process, stabilizing the glider.

Oct. 22 (O.W.) –Wind 10–15 miles. Tate & family called in morn. Geo. Baum called. Went to K.H. to get provision. Looked over situation of 1900 camp. **(A.O.)** — Very bright sun. Wind 10–15 m.p.h. West.

The 1911 glider after turning over on landing. (credit: Wright State University)

Oct. 23 (O.W.) — Light drizzle. First flight, wires of vert. rudder crossed. In second flight turned over backward when Ogilvie & Lorin let go. Cause of accident due to difference in velocity of wind on surface and 6 feet above. Broke vertical & horizontal rudders. **(A.O.)** — Blowing 20–25. Fine rain. On Kill Devil Hill in afternoon. O.W. turned over backward. Rudder wires crossed. Back horizontal rudder too small. Rudder broken. Made new horizontal rudder 27 sq. ft., 9 ft. by 3 ft. Put new sticks in rudder. [Added subsequently: Orville's account is a little different here. As I remember it, this turnover was the first thing that happened!]

Extending the tail, note the hand-drill that Orville (left) is using. (credit: Photo: Joyner Library)

Oct. 24 (O.W.) — Sunshine. Wind 20–25 [M.P.H.] on ground. Wind at top [of] hill as high as 40 miles at 6 ft. [above ground], 50 miles [at] 12 ft. Just below top, 35 miles at height of 6ft. 22 miles [at height of] 6ft. at bottom and 30 miles at height of 12 ft. Made about 20 glides ranging from one [minute] to 9 min. 45. Sec. [Two of] 7' 15" [and] 5' 29" more than 50 ft. above top hill. Measured a space of about 40 yards over which machine seemed to glide without any loss of speed at angle 6°. Hung 8 lbs. sand 7 ft. out. **(A.O.)** — Fine and sunny. 8 lbs. out front at 7 ft. from front edge. Success- successful soaring up to 10 min. by O.W. Others 7 ½ m. and 5 ½ m. aggregating nearly 1 hour. Only just enough control. Very difficult. I did a few glides late in afternoon. M/c travelled 40 yards without loss of speed on 6° slope. Wind condition. On crest 40 m.p.h. Kill Devil. 12 ft. up, 50 m.p.h. Just below crest, 30–35 m.p.h. O.W. was sometimes 50 ft. above top of hill.

Group portrait in front of the glider at Kill Devil Hill. Sitting (L to R): Horace Wright, Orville Wright, and Alexander Ogilvie; standing (L to R): Lorin Wright, and a group of journalists, including Van Ness Harwood of the New York World, Berges of the American News Service, Arnold Kruckman of the New York American, Mitchell of the New York Herald, and John Mitchell of the Associated Press. (credit: Wright Brothers Papers, Library of Congress)

Oct. 25 (O.W.) — Glides on West [Hill] & Kill Devil [Hills]. 12 lbs. sand 8 feet out. **(A.O.)** — Wind 15–20 m.p.h. dying away to 10–15 about midday. O.W. tried quartering. One sideways glide. I did some soaring glides, about 15. Longest 59 sec. Very difficult to stop m/c if sliding sideways. One stall and bump. Sometimes 40 ft. above hill.

Lorin Wright (left) and Alec Ogilvie ready to lift the glider prior to hand launching. A bag of sand in the front counterbalanced the weight of the extended fuselage, counteracting the tail. (credit: Flugsport, November 29, 1911)

Oct. 26 (O.W.) — Wind at top of hill 20–25 miles. Gliding on Big Hill from 12 to 3. Vane put out 5 ft. in front of machine. Control much improved.

- Small V Rudder 3' 3" X 14"
- Ex. Rudder 3' 9" X 15"
- B Rudder 5' 2" X 18"

Flying and then bringing the glider back up the dune. (credit: Wright Brothers Papers, Library of Congress)

(A.O.) — Wind 15–20 decreasing after 1 p.m. Warm and sunny. On Big Hill wind 25 m.p.h. on top. Only just enough for soaring. Put front vane 6 ½ sq. ft. area, 5 ft. from front edge. Much better steering. Might be doubled in effect. Weight of 12 lbs. 8 ft. from front edge. 25 flights, longest 1m. 5s. [Added subsequently: Incorrect unless it referred to my longest glide]. O.W. soared 2 ½ min. and landed above start, nearly over the crest. O.W. repaired my watch. Sand in escapement.

..NOTICE..
PHOTOGRAPH BY
THE INTERNATIONAL NEWS SERV
200 William Street

The wonderful "motorless biplane glider" invented by the Wright brothers, falling with Orville Wright, who narrowly escaped death. In a test of the glider last Monday (Oct. 23) Orville Wright flew for ten minutes in the teeth of a 40-mile gale. Then the machine turned turtle completely in the air and began dropping with the aviator hanging head downward. With wonderful agility, Wright squirmed and pulled until he regained a normal position in the upturned machine. This was accomplished in the five seconds it took the machine to reach the sands of Kill Devil Camp, Kitty Hawk, N.C., where he is making his experiments. This is one of the most remarkable photographs of an aviation accident ever taken.

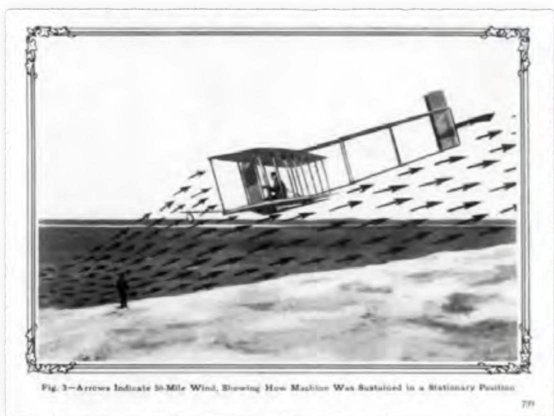
These accidents resulted in sensational newspaper reports and photos. The tendency of the glider to stall and spin was still not overcome. (credit: Wright Brothers National Memorial Collection)

Oct. 27 (O.W.) — Went fishing and to Manteo. Machine weights 170 lbs. in later glides, include 12 lbs sand. **(A.O.)** — Calm and sunny…

Left, Centre: Soaring high above the takeoff point while spectators look on. Right: Alec Ogilvie during a soaring flight. (credit: Joyner Library)

Oct. 28. (A.O.) — Raining and blowing hard. Took down machine for fittings.

Oct. 29. (A.O.) — Left for Manteo. **Oct. 31. (A.O.)** — Arrived Dayton **Nov. 1 (A.O.)** — Left for New York.



Left: In his December 1911 Popular Mechanics article, Victor Lougheed tried to explain the phenomena of hovering or how the glider was sustained in a stationary position to soar for almost 10 minutes. | Right: Our current understanding of ridge lift. (credit: Soaring Society of America)

In Closing

Katharine Wright wrote to Alec on November 8, 1911 that Wilbur Wright was —up to his neck in lawsuits, and Orville was full of energy and enthusiasm since his return from Kitty Hawk. He had hoped to make a good many improvements in the machine for the next year and he now spent much time at the drawing board.

Success again! Soaring high, but the flights were not as long as those on October 24. (credit: Joyner Library)

On the ‘fun side’, Orville’s 9 minute 45 second soaring flight was the beginning of modern-day soaring. On the ‘business side’, believing that the front vane would prevent the airplane from stalling, the “stabilizing device” was added to the Wright Company’s Model C series.

10/24 + 1911 + 9:45 = SOARING100 Celebration

The gliding community celebrated the centennial of Orville Wright’s history-making flight, as it is seen to be the beginning of modern soaring. In conjunction with this celebration, several aeronautical researchers looked closer at why Orville decided to experiment with a glider again, and how the structure of the glider changed during these two weeks. This provided insight into the contemporary knowledge and understanding of aeronautics.

One way to learn about the glider and the surrounding events was the initial thought of building and then flying a reproduction of that glider during *SOARING100* at the dunes of Jockey’s Ridge State Park. Three groups (from Wichita, Kansas, St. Mary, Maryland and Richmond, Virginia) researched and started to exchange information in late 2009.

Each group made good progress, but then encountered problems along the way. As a result, the visiting public could admire two reproductions; at Jockey's Ridge State Park, one reproduction was displayed as an uncovered structure, inviting curious on- lookers to see how an early aircraft was built. The just completed reproduction, built by the team from Richmond, was on display at the Pavilion of Wright Brothers National Memorial.

The as yet uncovered glider of the 'Dayton Team"" from St. Mary, Maryland on display at the SOARING100 event. (credit: Simine Short)

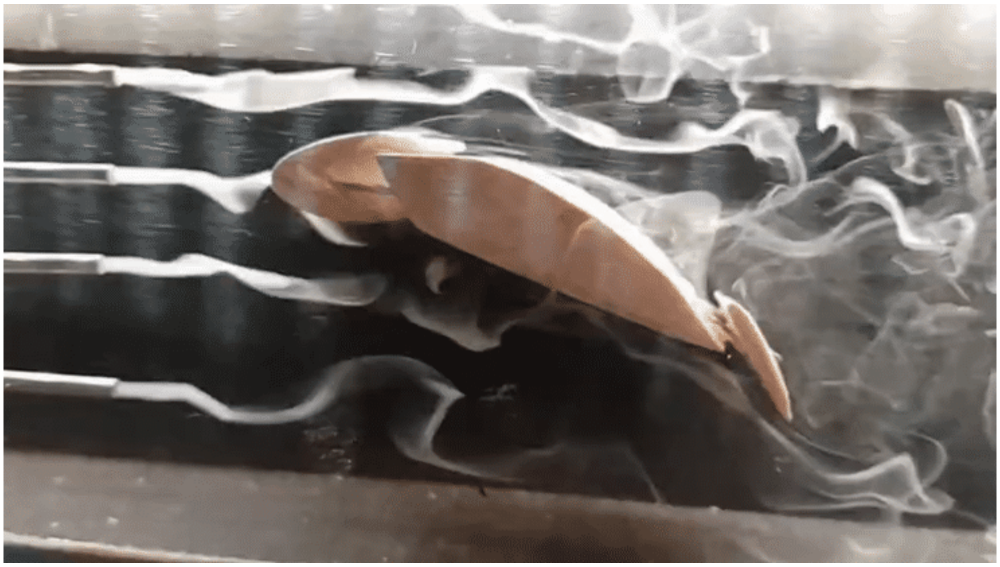
Resources

- *Flying, Fast and Furious* by August Post in *The World's Work* of July, 1911. — "Aviators had, before this summer, to their credit among other daring and skilful deeds these achievements: An entire working day of more than eight hours spent in an aeroplane…"
- *Aviation Victims Now Number 100* clipped from *The New York Times* of October 15, 1911. — "Death Roll Reaches That Point with Fatalities at Rheims and Berne. | Sixteen were Americans. | France Suffered the Most, Losing 37 of Her Aviators, One a Woman — Germany Lost Twelve."

- *Aviators Not at All Dismayed by Toll of Lives the Air Has Taken* clipped from the *New York Tribune* of January 22, 1911. — "Ten Times as Many Airmen Killed Last Year as in 1909, but Total Distance Flown in 1910 was Twenty Times as Great as in Previous Twelve Months."
- *Golden Jubilee of Soaring* by A.E. Slater as it appeared in *Sailplane & Gliding* Vol. XII, №6, December, 1961. — "What was the first sustained soaring flight in history? Pioneers like Lilienthal and Pilcher sometimes hovered for a few seconds…" The article goes on to provide extensive quotes from the diaries Alexander Ogilvie and Orville Wright, which were both kept during the October, 1911 Kitty Hawk flights.
- *The Secret Experiments of the Wright Brothers* as it appeared in *Popular Mechanics* Vol. 16, №6 in 1911/12. — "So many extravagent stories have been printed concerning the interesting experiments with a new glider, which the Wright brothers have been making of late at Kill Devil Hills, N.C., that Popular Mechanics Magazine sent an acknowledged authority…"

Note that where possible, we have retained the sepia and cyanotype colouring of the original photographs, to provide the reader with a more authentic sense of the period in which the story takes place. Also, thanks to Editorial Assistant Michelle Klement for her invaluable assistance in preparing this article for publication. *Read the next article in this issue, return to the previous article in this issue or go to the table of contents. A PDF version of this article, or the entire issue, is available upon request.*

Rediscovering Martin Simons



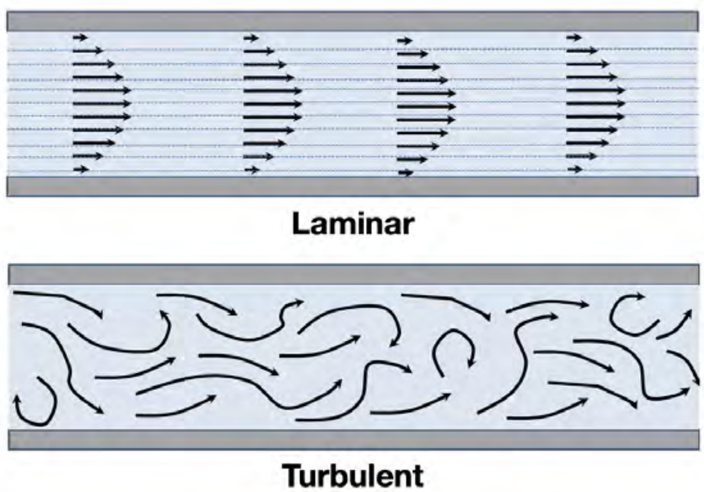
What every RC soaring shop needs: a desktop wind tunnel such as that created by Mark Waller and presented on YouTube. A clip is used here with his kind permission. We have provided a link to Mark's excellent video in Resources, below.

Part V: Turbulators as discussed in two of the noted author's model aircraft books.

In the previous part of this series (see Resources *below for link), there was a look at Martin Simons' books related to model aircraft and in particular how they dealt with the subject of centre of gravity. This month, we turn to Simons' discussion of another subject of interest to the RC soaring community: turbulators. We start with comments from curator Peter Scott and then follow with the text and images from Martin's books, unless otherwise noted. — Ed.*

This is more material from Martin Simons' excellent books, this time on the subject of turbulators. The Reynolds Number is central to fluid flow and has always been a bit of a mystery to me. Aircraft designers use scale models in their wind tunnel experiments so their experience is relevant to us. There will be more about the Reynolds Number in a future article but as Martin mentions it I have quoted a brief account from BYJU's (see *Resources*, below):

> "Reynolds number is a dimensionless quantity that is used to determine the type of flow pattern as laminar or turbulent while flowing through a pipe. Reynolds number is defined by the ratio of inertial forces to that of viscous forces.
>
> "If the Reynolds number calculated is high (greater than 2000), then the flow through the pipe is said to be turbulent. If Reynolds number is low (less than 2000), the flow is said to be laminar.
>
> "The Reynolds number is named after the British physicist Osborne Reynolds. He discovered this while observing different fluid flow characteristics like flow of a liquid through a pipe. He also observed that the type of flow can transition from laminar to turbulent quite suddenly."



Laminar versus turbulent flow. (credit: Adapted from Wikimedia under CC BY-SA 3.0)

From here on all text and images are from Martin's books, in this case just two.

Model Flight

3.18 Laminar and Turbulent Flow

In search of lower drag, much attention has been given, in recent times, to the flow of air within the boundary layer, the layer of air which is dragged along by friction with the skin of the wing rather than simply flowing past it. The boundary layer is often decisive in deciding when a wing stalls, since separation begins first in this layer. Within the boundary layer, two very different kinds of flow occur, laminar and turbulent (Figure 3.23).

A *laminar* boundary layer is one in which the flow near to the skin of the wing is arranged in very thin sheets or laminae which slide smoothly over one another with very little frictional resistance. A laminar boundary layer creates little skin drag. A *turbulent boundary* layer is very disturbed, particles moving up, down and sideways rapidly. This creates more frictional drag on the wing surface. The turbulent boundary layer is also thicker than a laminar one, so the general streamlined flow outside the boundary layer has to pass over what is, in effect, a thicker shape than if the boundary layer is all laminar. This increases form drag.

On full-sized aircraft, the boundary layer over a wing usually begins laminar, but after a very short distance, the smooth sliding flow breaks up and the boundary layer becomes turbulent (Figure 3.24).

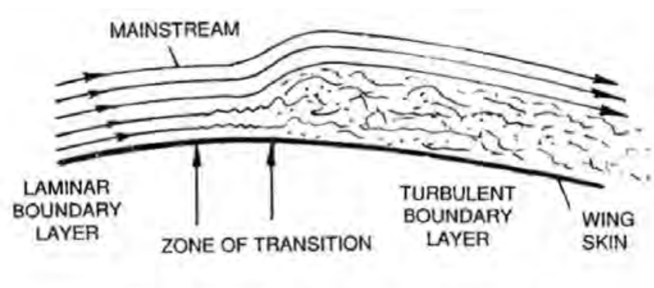


Figure 3.24 Boundary layer transition on full-sized aircraft

A rough visual impression of what happens may be obtained by observing the way water spreads out over a smooth surface, such as a bath or sink bottom, when a tap is turned on. The flow is laminar at first, but at some distance from the point where the jet of fluid strikes the surface transition occurs and turbulent flow, with an increase in depth, prevails. The boundary layer over a wing, although invisible, closely resembles this. Once transition takes place, the process cannot be reversed, so high skin drag continues on a wing aft of the transition, all the way to the trailing edge. (Experiments have been done with suction through small holes in the wing, to remove the turbulent boundary layer after it forms. This can restore laminar flow, but it soon changes again to turbulent. The suction has to continue to the trailing edge.)

Quite small defects, such as rivet heads and barely detectable dimples in the wing skin, fly specks and paint chips, can spoil even the small amount of laminar flow that exists. Hence full-sized aircraft often fly with fully turbulent boundary layers.

3.19 Scale effects

A few centimetres behind the leading edge of a large aeroplane the boundary layer usually becomes turbulent. Although the skin drag is high, at least the main airflow is not forced away from the surface. Model wings behave differently from full-sized ones in this respect. On a model wing, the few centimetres of laminar flow may extend from the leading edge to some point quite well aft on the wing, how far depending on the *chord* of the wing at each point, and the *speed of* flight. This at first sounds as if a model should have an advantage, in terms of profile drag.

Unfortunately this is not the case. A laminar boundary layer on a model wing, just because it does create less skin drag and has less transfer of flow energy to the wing, tends to separate from the surface altogether as soon as the point of minimum pressure (maximum flow speed) is passed. In the worst case, this separation is total. The wing stalls very early. Slow free flight models with thick wings and small chords suffer from such premature stalling and perform badly. With radio controlled models, if the wing is not too thick, what normally happens is the formation of *separation bubbles* (Figure 3.25).

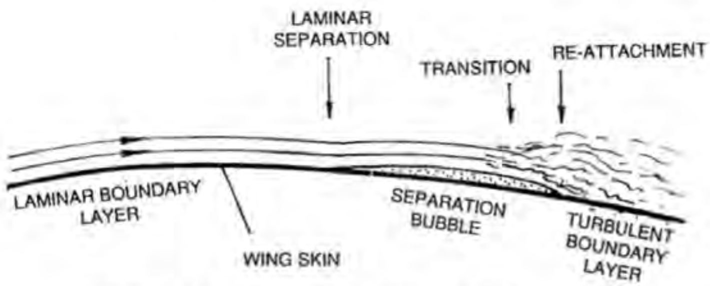


Figure 3.25 Formation of separation bubble

When the laminar boundary layer leaves the wing skin, after a short delay it usually breaks up into a turbulent layer, which is thicker. This increase of thickness allows it to reattach to the wing. Underneath the separated area is a ‘bubble’ of stagnant air which does not move downstream with the flow, but remains on the wing, with a circulation of its own. The separation bubble may be several centimetres long in the chordwise direction, and on a small model may cover most of the upper wing surface. There will usually be a lower surface bubble too.

The larger the wing, and the faster it flies, the less important these separation bubbles become. They do occur on full sized sailplanes, but on a large wing at high flying speed, a small separation bubble has little influence. On a model wing, flying slowly with small chord, such a bubble can cause a very serious deterioration in performance. It creates an effective disturbance to the mainstream airflow and this creates additional form drag. The effect of a separation bubble may be likened to opening a small airbrake, a few millimetres high, all the way from wing tip to wing tip, on the model. Model wings are therefore never as efficient as full sized ones.

3.20 Turbulators

It sometimes improves the performance of a small chord, slow flying model if the formation of a separation bubble can be prevented by triggering boundary layer transition before the minimum pressure point is reached on the wing. This can sometimes be done by using *turbulators* (Figure 3.26).

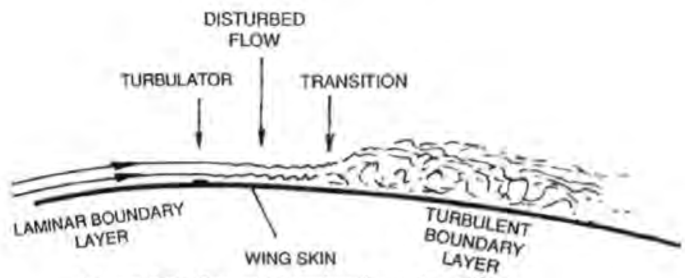


Figure 3.26 Forced boundary layer transition with turbulator

These are very thin strips of narrow tape, stuck onto the wing spanwise, some small distance ahead of the point where the separation bubble would be expected to develop. The turbulator should not be too thick, since if it is so, it might have a worse effect on performance than the separation bubble itself. There is some evidence to suggest that laying the tape in a fine sawtooth or zig zag fashion produces a greater effect. It is also thought by some model fliers that using a slightly rough wing covering material, such as fabric lightly doped, instead of very glossy film or paint finish, helps to bring about boundary layer transition. Very little definite information is available here as a guide, but turbulators are worth trying if there is any doubt about the performance of a particular model.

The tape strips can be placed in position and removed fairly easily, and the resulting change in model behaviour observed. The idea of using several turbulators or boundary layer *invigorators* one behind the other is also worth investigation. The intention is not to promote turbulent flow over the whole wing, but to preserve the laminar boundary layer over the forward part of the skin as far as it is safe to do so, then to cause transition just before the laminar separation point. Turbulators may be worthwhile on both upper and lower wing surfaces and experiment is, at present, the best means of finding out where they should be placed.

The separation bubble problem is only one aspect of the scale effect. Another problem is caused by the inherent viscosity of the air. Movement through viscous fluids, like treacle, is much more difficult than through less viscous substances like water or air. Although air is not very viscous, none the less it has a certain stickiness. For a very large aeroplane, this is relatively unimportant, but for small creatures, such as gnats and midges, flying is extremely difficult. To such small wings the air seems almost like treacle. To compensate, small insects beat their wings at extremely high rates, so the rate of airflow over their surfaces is quite high. Model aeroplanes come between these extremes, not so small as insects, but not so fast as full-sized aeroplanes. In relation to size of wing and speed, the relative viscosity of the air increases drag at all times. The fast flying model with large wing chord always has an advantage over the small, slow one with narrow chord for this reason, quite apart from the separation bubble effects mentioned above. Viscosity effects are felt more strongly by thick wings, which is another reason for using thin aerofoils on models, when minimum drag is required.

The scale effect is often expressed in terms of the Reynolds number or **Re**. Full-sized powered light aeroplanes fly at Re numbers greater than 1,000,000, sailplanes and ultralight aeroplanes rather less than this at their lower speeds. Pylon racing models and multitask sailplanes reach Re about 500,000 at their maximum speeds and widest wing chords. Most sports models fly at Re about 100,000 up to 300,000. Gnats and other small insects are down in the 5 to 10,000 Re range.

8.4 The Leading Edge Radius

The reason for the low critical Re of these profiles was, Schmitz argued, their combination of very small nose or leading edge radius and relatively small upper surface curvature. The stagnation point of the airflow near the leading edge of a wing at a positive angle of attack is always slightly below the geometric leading edge. The boundary layer begins its journey over the upper surface by flowing around the leading edge itself. At high angles of attack, the flow in this neighbourhood is even slightly upstream (Fig. 8.7).

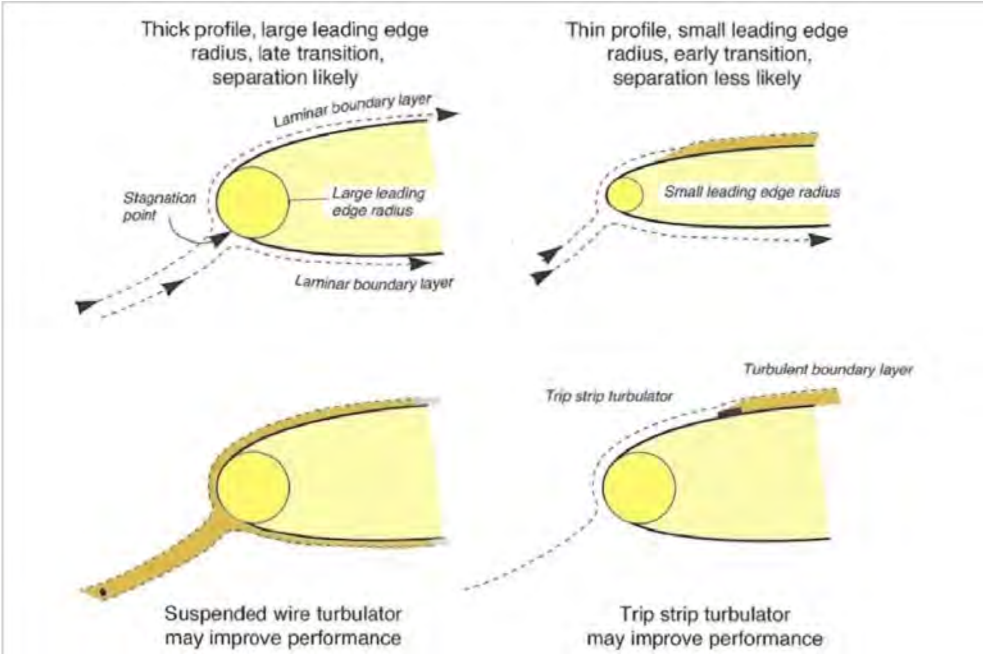


Figure 8.7 Flow near a wing leading edge.

From near stagnation, the boundary layer moves towards a low-pressure region on the upper surface and accelerates. If the profile has a smoothly rounded leading edge of large radius, as thick airfoils usually do, the boundary layer can follow this curve easily and remains laminar. If the leading edge radius is small, the boundary layer is compelled to flow round a very sharp curve or even a knife-like edge, changing direction very sharply while accelerating rapidly towards the low pressure point which, on profiles of this early kind, lies only a small distance behind the leading edge. The boundary layer inertia may be expected to overcome the viscous forces at this sudden change of direction and separate from the wing surface. It reattaches immediately the corner is passed, but a very small separation bubble, what Schmitz called a ‘rolled over vortex’, forms in the boundary layer. The small leading edge radius thus introduces some artificial turbulence into the airflow, encouraging early transition. The reattachment is not instantaneous. A separation bubble forms and the boundary layer reattaches some distance aft of the leading edge.

8.5 Turbulators

The effect of the sharp leading edge is very similar to that of a turbulator wire in the main stream ahead of the leading edge. A similar effect is obtained by mounting, on or just behind the leading edge, a raised ‘trip strip’ or leading edge turbulator, which may be of various forms and sizes. In each case, what is required is a brief separation bubble followed by turbulent reattachment downstream. A turbulator that is too small will not achieve the early transition, but one, which is too large, may itself cause flow separation.

Once the boundary layer has been forced into turbulence, it remains important that it should not separate from the upper surface. A profile with a turbulator or sharp leading edge still requires the air to flow against an adverse pressure gradient once it has passed the minimum pressure point. A thin profile presents a less formidable task to the boundary layer, so separation may be avoided, on the upper surface. On the underside, at high angles of attack flow separation is unlikely since once the stagnation point is passed, the flow tends to follow the surface of a thin profile closely. At low angles of attack underside separation is very likely behind the leading edge, but reattachment is still probable before the trailing edge.

8.6 Separation Bubbles

Schmitz did not investigate in detail the size of separation bubbles over his airfoils, and as shown in Fig. 8.3, these may be very extensive. The Go 801 profile tested by Kraemer is of smaller thickness than the N60 (10% as against 12.6%). It has a slightly smaller nose radius, but greater camber (7% at 35% compared with 4% at 40%). It thus comes somewhat closer to the thin curved plate profile, and its critical Re is slightly lower than that of N60. Some detailed measurements made by Charwat at the University of California in 1956–57 showed that a profile of the shape shown in Figure 8.8, with the small nose radius of 0.7%, also exhibited separation bubbles very similar to those of the 801 profile. The airfoil in this case, designed by Seredinsky following one of Schmitz’s suggestions, was based on a profile of orthodox type, but the underside of the leading edge was cut away to produce a profile with room for wing spars, yet with the advantages of a small leading edge radius. In these tests, a separation bubble formed over about 35 to 40% of the chord. Above 7° angle of attack the bubble moved forward. Turbulent flow separation occurred over the rear prior to the stall, but the profile worked well.

The effect of the separation bubbles formation and movement is of considerable significance. The bubble is sufficiently large to divert the main airstream over the upper surface round a longer path, just as if the profile was more cambered. It has been established that a profile with the maximum camber point well forward develops a high maximum lift coefficient. The result of this effective camber increase *together with bubble movement forward* at high angles of attack, is to increase the slope of the lift curve above that which is predicted by theory. Such evidence as there is from model operations tends to confirm that some airfoils on small free flight models behave erratically. This may be attributable to shifting of the separation bubble, and its flattening effect on the chordwise pressure curve, to and fro on the wing as the angle of attack varies slightly. The fluctuating pressures over the profile cause sharp changes of the pitching moment that is already large because of the high camber of such wings. The hysteresis loop is caused by the bursting and re-forming of the separation bubble. A model in this critical Re region, capable of stable flight in smooth air, may become uncontrollable in rough conditions. These factors come together with the inherently pitch-sensitive qualities of the high aspect ratio wing to make the model sailplane operators difficulties more severe. Providing these problems can be overcome, there is no doubt that, for high performance at very low wing Re, thin, small leading-edge-radius profiles, appropriately cambered, are excellent.

By adding turbulators to thicker profiles, the low speed performance may be improved. The turbulators used by Schmitz and others were usually wires mounted ahead of the leading edge on light outriggers. For practical models, wires may be replaced by thin elastic or plastic strings. These are, however, a nuisance in operation and the leading edge 'trip strip' is easier to manage. Such strips have the advantage that they may be lightly pinned or 'tack glued' in various positions for trial, and moved or changed in size to give best results. If the critical Re of the profile chosen is already low turbulators cannot have much influence on still air performance. However, by triggering separation at a fixed point on the wing, they probably stabilise the position of the separation bubble, reducing the fluctuations of moment coefficient. The result should be an improvement in controllability of the model.

8.7 The Effects of Structure and Surface

Models constructed on traditional lines may in effect have turbulators built in. The sag of tissue or other thin covering behind the leading edge spar between the ribs creates a bump in the profile. This may have a beneficial effect on transition, and the good performance of some small, light models can be explained only in this way. Among his tests on the Go 801 Kraemer included tests of a paper-covered model which showed that sub-critical flow prevailed down to Re 42,000, comparable with the same airfoil with a turbulator wire. Wind tunnel results on a number of balsa wood and tissue covered wings, carried out at Stuttgart University and reported by Dr. D Althaus *(Profilpolaren* fur *den Modelflug, Vol.* 2) have shown the same effect at free flight model wing sizes and speeds. This suggests that attempts by modellers to preserve very accurate profiles over the front part of low *small* model wings are sometimes misguided. The simple tissue- or film-covered leading edge may prove more efficient than one with a perfect surface, especially if the wing profile used is on the thick side with a large leading edge radius. It should be emphasised, nevertheless, that when the model is large enough or fast enough to avoid sub-critical Re problems, turbulators and surface irregularities at the leading edge cause drag to rise and **cl** max [coefficient of lift] to fall. This may be confirmed by study of the many other wind tunnel test results now available.

The Seredinsky type of wing (Fig. 8.8) resembles the wing profile of some larger soaring birds. Although difficult to construct, it may prove effective on smaller models, or models with very high aspect ratio and small iving chords. The leading edge is similar to that of a simple curved plate, but the thickening of the profile on the underside provides room for a strong main spar without much effect on the upper surface flow.

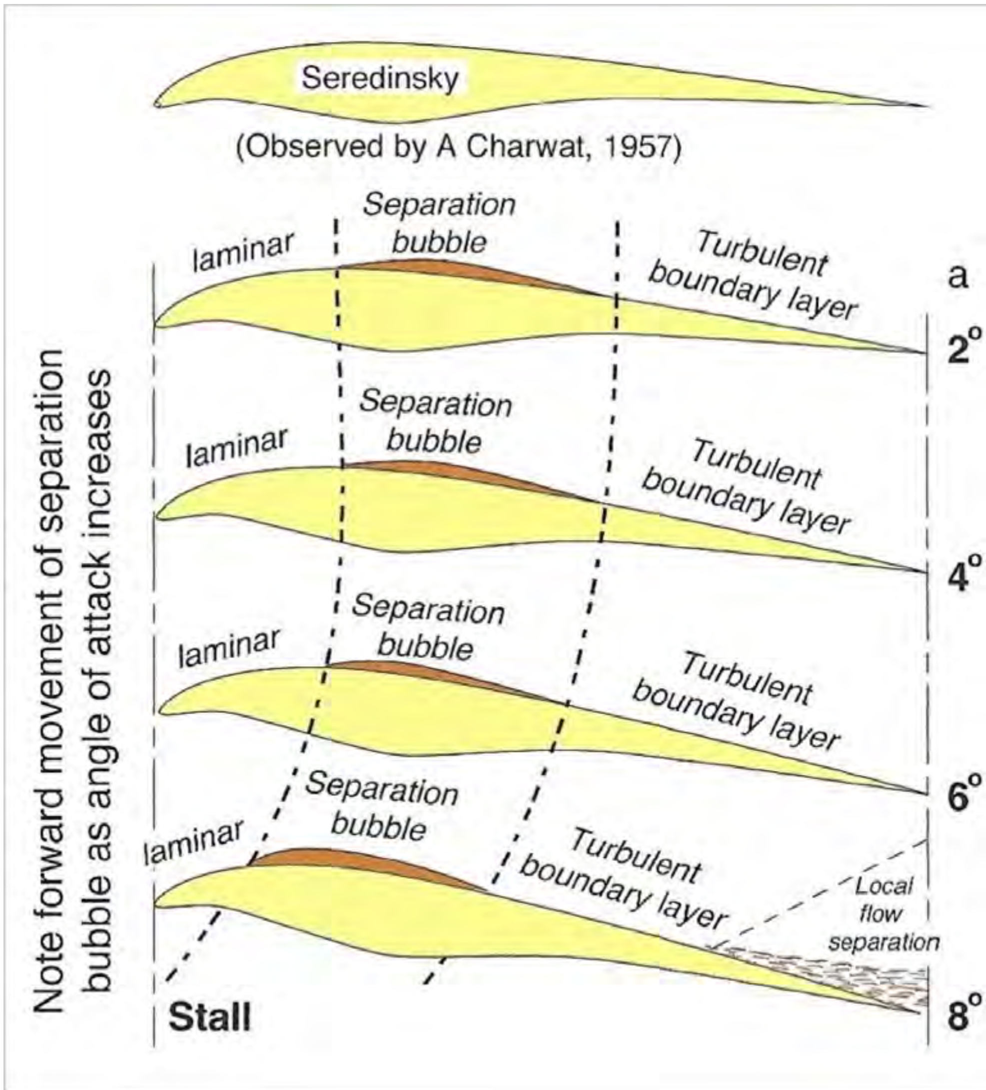


Figure 8.8 Separation and re-attachment on the Seredinsky profile.

8.8 Boundary Layer Invigorators

Research by Martyn Presnell in a wind tunnel at Hatfield showed that improvements in the performance of freeflight model sailplanes and rubber driven airplanes can be achieved by the use of multiple 'trip strips' or, in Presnell's terminology, 'invigorators'.

Test wings using the Benedek 6356b were constructed from materials like those used in a typical FI A (A2) sailplane model. Balsa wood wing ribs and spars were used, the framework being covered with tissue paper, doped. In one case, the forward third of the wing was skinned with thin sheet balsa. Not only were lift and

drag forces measured, but some flow visualisation tests were done. These involve coating the test wing with pigmented kerosene to reveal the nature of the boundary layer. Where the boundary layer is turbulent the kerosene evaporates rapidly, leaving a film of pigment. Within the laminar separation bubble, evaporation is less rapid so the flow of the air nearest the wing skin can be seen as the liquid moves upstream {}. In the fully laminar flow regions the kerosene remains liquid longer and flows in the normal downstream direction. The flow separation point and reattachment downstream of the bubble can then be discovered for each angle of attack. (Modellers have sometimes noticed that, when flying in the late afternoon or early evening at dew fall, dew deposited on a wing before flight will still sometimes be present after the flight on the leading edges where the flow is laminar, but evaporates from the rear parts of the wing where turbulent boundary layers are expected.) In Presnell's tests the addition of a single turbulator at 5% of the wing chord improved the measured lift and drag figures, as expected, at Reynolds numbers below 40,000, although the separation bubble was still present. The turbulator consisted of a thin strip of adhesive plastic tape 0.15mm thick and 0.75mm wide, running spanwise.

It was then found that the addition of further strips of the same thin tape at various positions on the chord aft of the turbulator resulted in further improvements of lift and drag figures. The best results at Re below 70,000 were found with five of these invigorators in the positions shown in Figure 8.9. The original 5% turbulator remained in place throughout.

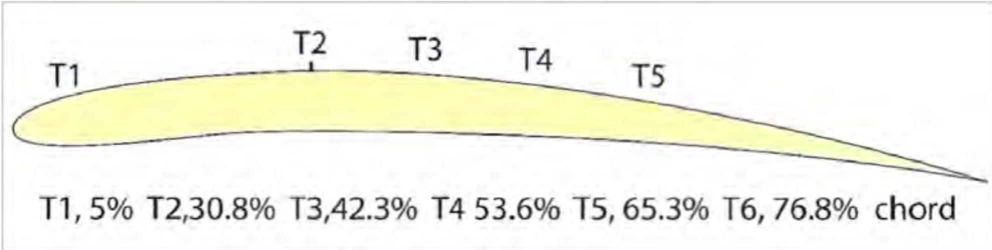


Figure 8.9 Benedek 6356b airfoil with turbulator and invigorators. From Martin Presnell.

Presnell noted that placing an invigorator within the separation bubble, as revealed by the kerosene, made no detectable difference. The first invigorator must be placed just aft of the reattachment point and the others spaced over the rear part of the wing in the turbulent boundary layer. The exact mechanism of the invigorators is not fully understood at present. It may be that they aid the already turbulent boundary layer to remain attached to the wing after the bubble has been passed. Presnell pointed out that several leading contest model flyers used invigorators with success.

Resources

- *Desktop Wind Tunnel* by Mark Waller on YouTube — "I am not sure why I made this. Just a bit of fun during lockdown and to satisfy my natural curiosity! It's an opportunity to try to photograph some cool images of airflow in different situations…"
- *What is a Reynolds Number?* by BYJU's. — "a dimensionless quantity that is used to determine the type of flow pattern as laminar or turbulent while flowing through a pipe. Reynolds number is defined by the ratio of inertial forces to that of viscous forces…"

Previously, in this series:

- *Rediscovering Martin Simons: Part IV* — Center of gravity as discussed in the noted author's model aircraft books.

Note that the following are simply examples (from AbeBooks) of where you can obtain copies the books referenced in this article. A quick search will reveal many alternatives including possibly your local secondhand bookstore:

Glider Patents

The Ampyx Power AP2 in workshop. This image was not part of the original patent filing and is provided here purely for the interest of our readers. (credit: ©2016 Karssing under Creative Commons Attribution-Share Alike 4.0 International)

US 2015/0266574 A1: Glider for Airborne Wind Energy Productions

This is the sixth in our series of glider-related selections from the files of the US Patent and Trademark *office (see* Resources, *below). They are presented purely for the interest and entertainment of our readers. They are not edited in any way, other than to intersperse the drawings throughout the text. Disclaimers: a) Inclusion of a given patent in this series does not constitute an expression of any opinion about the patent itself. b) This document has no legal standing whatsoever; for that, please refer to the original document on the USPTO website. — Ed.*

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(12) Patent Application Publication
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(54) GLIDER FOR AIRBORNE WIND ENERGY PRODUCTIONS

(71) Applicant: AMPYX Power B.V., AL The Hague (NL)

(72) Inventor: Richard Ruiterkamp, GH Den Haag (NL)

(21) Appl. No.: 14/625,652

(22) Filed: Feb. 19, 2015

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(63) Continuation of application No. PCT/EP2013/002446, filed on Aug. 14, 2013.

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CPC . ***B64C 31/06*** (2013.01); ***F03D 5/00*** (2013.01); *F05B 2240/921* (2013.01)

Abstract

A glider, a system and methods for electric power production from wind are disclosed. The glider includes an airfoil, onboard steering means for pitching, rolling and yawing the glider when airborne, sensor means that provide a first signal related to an absolute position of the glider, a second signal related to an air speed of the glider and a third signal related to an acceleration of the glider, a control device connected to the steering means for controlling autonomous flight of the glider based on the signals provided by the sensor means, and a connection means for a tether connecting the glider to a ground-based electrical machine constructed for converting a lift force generated upon exposure of the airfoil to wind and transferred to the ground via the tether into electric power. The system includes the glider, the ground-based electrical machine and tether.

Cross-Reference to Related Applications

[0001] This application is a continuation of International Application No. PCT/EP2013/002446, filed Aug. 14, 2013, and claims priority to EP 12181506.2, filed Aug. 23, 2012.

Background of Invention

[0002] 1. Field of Invention

[0003] The invention relates to a glider for electric power production from wind. The invention further relates to a system for electric power production from wind.

[0004] 2. Brief Description of Related Art

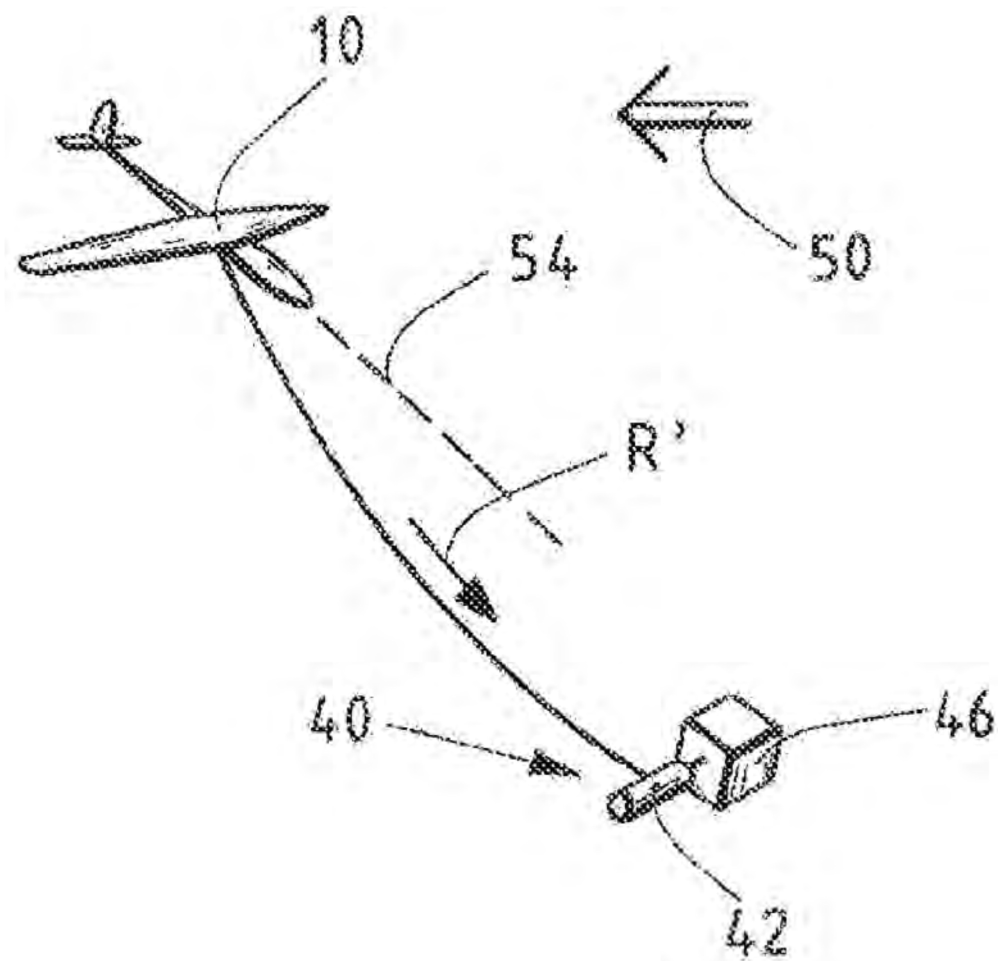
[0005] The production of electric power from wind is generally accomplished by airfoils or structures with an aerodynamic profile, which produce lift forces upon exposure to wind. Thereby, energy is extracted from the wind, which can be converted into electricity, for example by exploring said lift forces to drive an electrical generator. Well known wind turbines for instance comprise a rotor with aerodynamically profiled rotor blades, wherein the lift forces of the rotor blades cause the rotor to turn. The rotor is mounted to an electrical generator, which is for example located on top of a tower, for production of electricity.

[0006] In order to explore wind energy resources at altitudes above a few hundred meters over ground, where the average wind is stronger and steadier due to less disturbing interaction with the earth's surface, it has been proposed to use airborne airfoils. These concepts are often referred to as airborne wind energy or airborne wind energy production.

[0007] One of the challenges of airborne wind energy production is the transferal of energy extracted from the wind at high altitudes to the ground. Two general approaches are proposed, the first providing for an airborne generator and subsequently a relatively heavy flight object, and the other providing for a ground based generator, wherein the energy extracted from the wind has to be mechanically transferred to the ground.

[0008] An example of the latter approach is the so-called pumping kite concept. A kite flies downwind of a ground-based generator connected to its steering lines, thereby pulling the lines and driving the generator as the kite departs from the generator. In order to recover the lines, the generator is driven as a motor to pull back the kite. During this phase, the kite is steered to exert less pull on the lines, so that power consumption for pulling back the kite is less than the power produced by the kite pulling the lines before.

[0009] The underlying problem of the invention is to provide for electric power production from wind using an airborne airfoil, wherein in particular the integrated energy yield is to be improved with respect to the prior art described above.



Brief Summary of the Invention

[0010] According to the invention, this problem is solved by a glider for electric power production from wind, said glider comprising an airfoil, onboard steering means for pitching, rolling and yawing the glider when airborne, sensor means providing a first signal related to an absolute position of the glider, a second signal related to an air speed of the glider and a third signal related to an acceleration of the glider, a control device connected to the steering means for controlling autonomous flight of the glider based on the signals provided by the sensor means, and a connection means for a tether connecting the glider to a ground-based electrical machine constructed for converting a lift force generated upon exposure of the airfoil to wind and transferred to the ground via the tether into electric power.

[0011] A glider or sailplane in terms of the invention in particular is a fixed wing aircraft, especially without propulsion means such as propellers or jet engines, wherein on-board steering means allow for full flight maneuverability of the glider around its longitudinal axis, its lateral axis and its vertical axis. In terms of the invention, these three principle axes form a Cartesian coordinate system, wherein the origin of said coordinate system is defined to be at the center of gravity of the glider.

[0012] In general terms, with reference to straight and level flight, the longitudinal axis relates to the direction of motion, the vertical axis relates to the direction of lift and the lateral axis is essential horizontal to complete a Cartesian coordinate system.

[0013] The glider for instance comprises a fuselage and a main wing, wherein the main wing constitutes or comprises an airfoil. In this configuration, the longitudinal axis is essential parallel to the fuselage, the lateral axis is essential parallel to the main wing and the vertical axis is perpendicular to both the longitudinal and the lateral axis. Those skilled in the art will appreciate that the glider can have another airplane configuration, for instance an all-wing aircraft, with appropriate definitions of the principle axes.

[0014] In terms of the invention, rolling refers to a rotation of the glider around its longitudinal axis, pitching refers to a rotation of the glider around its lateral axis and yawing refers to a rotation of the glider around its vertical axis.

[0015] A glider provides the advantage of low aerodynamic resistance or drag and a high aerodynamic lift due to the fixed wing with rigid aerodynamic profile or airfoil, respectively. This is in particular beneficial, because the energy effectively extracted from the wind strongly depends on lift and drag, in particular on the so-called lift-over-drag-ratio.

[0016] The sensor means and control device of the glider according to the invention allow for unmanned flight, which reduces the total weight of the glider. Therefore, a larger amount of the total lift force generated by the airfoil is available for electric power production and thus increases the integrated energy yield.

[0017] For enhanced safety of the glider, the connection means in particular are arranged for releasable connection of a tether to the glider, wherein the tether is connecting or arranged for connecting the glider to a ground-based electrical machine.

[0018] The sensor means and control device also allow for automated optimization of the flight, in particular in order to maximize the lift force during the energy production phase and in order to minimize the pull on the tether during the recovery phase. Also, the flight during the recovery phase can be optimized for minimum duration.

[0019] In terms of the invention, a signal related to a specific parameter in particular is a measurement value or a set of measurement values, which is continuously or repeatedly taken during the flight and allows determination of the specific parameter.

[0020] The position of the glider in particular is the absolute position relative to the ground, which for instance is given in world coordinates, i.e. by longitude, latitude and height above sea level.

[0021] A signal related to the position for instance is the ground speed of the glider, which allows the iterative determination of the position of the glider starting from a known initial position. The ground speed in particular is the movement or velocity, respectively, of the glider relative to the ground.

[0022] In a preferred embodiment of the invention, the sensor means comprise a first position sensor, in particular a GPS sensor, i.e. a sensor according to the standard of the well known Global Positioning System. A position sensor in particular provides a direct measurement signal of the absolute position, which often is more precise than the iterative position determination. Those skilled in the art will appreciate that a position sensor can be a sensor according to the standards of any satellite based positioning systems, for instance the Galileo project, or can be based on other navigation technologies, such as RADAR.

[0023] Preferably, the sensor means comprise a second position sensor, in particular a GPS sensor, wherein the second position sensor is located at a given distance to the first position sensor. This allows determining the orientation of the virtual line between the first position sensor and the second position sensor and thus gives the orientation of the glider relative to the world coordinate system.

[0024] In contrast to the ground speed, the air speed is the movement or velocity, respectively, of the glider with respect to the surrounding air. In particular due to the presence of wind, the air speed in general differs from the ground speed. However, the air speed can be derived from the ground speed and the wind speed, i.e. the velocity of the air relative to the ground, wherein the ground speed for instance can be determined from the change in position of the glider with time.

[0025] It is preferred that the sensor means comprise an air speed sensor, in particular a pitot tube. Here, the signal related to the air speed is a direct measurement signal and generally more precise than the indirect determination of the air speed from the ground speed and the wind speed.

[0026] A pitot tube is a well-known instrument for determining the speed of an aircraft based on a measurement of a pressure difference, for instance the difference of an air pressure in a direction of flight (dynamic pressure) and an ambient air pressure in a direction perpendicular to the direction of flight (static pressure).

[0027] For instance, a pitot tube comprises a cylindrical tube oriented along the longitudinal axis of an airplane with a hole at the tip and a hole at the side, wherein the two holes are connected via internal passageways with a differential pressure sensor.

[0028] Preferably, the air speed sensor is a directional air speed sensor, in particular a multichannel pitot tube. For instance, a left-right pressure difference and a bottom-top pressure difference are measured in addition to the dynamic-static pressure difference described above.

[0029] For instance, a multichannel pitot tube comprises a cylindrical tube with a dome-shaped tip oriented with the longitudinal axis of an airplane, said tube comprising five holes at the tip for determining the dynamic pressure and at least one hole at the side of the tube for determining the static pressure. It can be provided for more than one hole for determining the static pressure, for instance four or even twelve holes evenly distributed along a circle around the side of the tube. The five holes at the tip are arranged with one hole at the center of the dome-shaped tip and the other four holes arranged at equal distance to the center hole, wherein these four holes are pair-wise oriented with the lateral axis and vertical axis of the air-plane, respectively. In this configuration, the left-right pressure difference is the pressure difference from the two holes oriented with the lateral axis, the bottom-top pressure difference is the pressure difference from the two holes oriented along the vertical axis, and the dynamic-static pressure difference is the pressure difference from the center hole at the tip and the average pressure from the holes at the side of the tube. Alternatively, the absolute pressure at each of the nine holes can for instance be measured independently, wherein the left-right pressure difference, the bottom-top pressure difference and the dynamic-static pressure difference are calculated from these measurements, respectively.

[0030] An acceleration of the glider can be a translational acceleration or, for a rotational movement is an accelerated movement, a rotational velocity and is induced by forces acting on the glider as a whole. A signal related to acceleration for instance is the second derivative with time of the position in case of a translational acceleration and the first derivative with time of the orientation in case of a rotational velocity.

[0031] In a preferred embodiment of the invention, the sensor means comprise an inertia sensor, which in particular provides for a direct measurement of a translational acceleration and/or rotational velocity. For instance, the inertia sensor measures the translational acceleration in three different directions and the rotational velocity around three different axes.

[0032] An appropriate inertia sensor includes in particular an accelerometer for measurement of a translational acceleration and/or a gyroscope for measurement of a rotational velocity.

[0033] The steering means preferably comprise at least one aerodynamically active control surface.

[0034] Aerodynamically active control surfaces are used to exert torque on the glider around one or more of the glider's principle axes. These control surfaces for instance comprise at least one aileron to mainly induce rolling and/or at least one elevator to mainly induce pitching and/or at least one rudder to mainly induce yawing. However, those skilled in the art will appreciate that other control surfaces known in aviation technology are also appropriate steering means in terms of the invention. In particular, a particular control surface can induce a rotation around an arbitrary axis, which does not correspond to one of the principle axes of the glider.

[0035] Besides control surfaces, the steering means of the glider for instance further comprise actuators, such as electric motors or hydraulic systems with pumps and cylinders, for moving the control surfaces. These actuators are for instance powered by an on-board power source, such as a battery. Alternatively, the connection means can include a power plug for connecting the glider to a ground-based power source via the tether, which significantly reduces the weight of the glider. In this configuration, the glider may still comprise a small emergency battery for continued safe flight in case of loss of connection to the ground.

[0036] A further embodiment of the invention is characterized in that the control device comprises a data storage unit for storing data related to flight characteristics of the glider and a data processor unit for deriving control signals for the steering means based on the stored data and on the signals provided by the sensor means.

[0037] Here, data related to flight characteristics for instance is a plane model, which in particular comprises a set of measured or simulated response curves for the correlation between the operation or change in operation of the steering means and the resulting state or change in state of the glider.

[0038] Preferably, the control device implements a Kalman filter. By this, the effect of measurement uncertainties on the control of the steering means and consequently on the flight of the glider is reduced.

[0039] It is further preferred that the control device implements an un-scented Kalman filter, for an unscented Kalman filter in particular allows for non-linear dependencies and correlations.

[0040] For optimized electric power yield, the control device preferably provides for a first operation mode for pulling on a tether connecting the glider with a ground-based electrical machine and wherein the control device provides for a second operation mode for approaching the electrical machine.

[0041] The two operation modes in particular differ by the intended flight path or flight pattern, respectively. For instance, the flight pattern of the first operation mode is a high lift flight pattern with mainly crosswind flight of the glider, while the flight pattern of the second operation mode comprises a mainly straight flight path of the glider against the wind.

[0042] In a further preferred embodiment of the invention, the glider comprises at least one aerodynamic control surface for varying a lift coefficient of the airfoil and/or for varying a drag coefficient of the airfoil and/or for varying a drag coefficient of the glider. This can for instance optimize lift and/or drag of the glider optimized with respect to the current operation mode. In particular, high lift and low drag, as is beneficial for the first operation mode, could delay descent of the glider and thus result in a slower return during the second operation mode. It is therefore of advantage, if the lift could be reduced and/or the drag could be increased during the second operation mode.

[0043] Suitable control surfaces are so-called spoilers located on top of the airfoil, so-called slats located at the leading edge of the airfoil, so-called flaps located at the trailing edge of the airfoil and so-called air brakes, which affect only the drag coefficient of the whole glider.

[0044] Additionally or alternatively, the airfoil may comprise a variable aerodynamic profile, which is another way for varying the lift coefficient and/or the drag coefficient. An airfoil with variable aerodynamic profile for instance is semi-rigid and can be modified in its curvature.

[0045] The underlying problem of the invention is also solved by a system for electric power production from wind comprising a glider according to the invention, a ground-based electrical machine and a tether connecting the glider with the electrical machine, wherein the electrical machine is constructed for converting a lift force generated upon exposure of the airfoil to wind and transferred to the ground via the tether into electrical power.

[0046] The problem is further solved by the use of a glider according to the invention for production of electric power from wind.

[0047] Further characteristics of the invention will become apparent from the description of the embodiments according to the invention together with the claims and the included drawings. Embodiments according to the invention can fulfill individual characteristics or a combination of several characteristics.

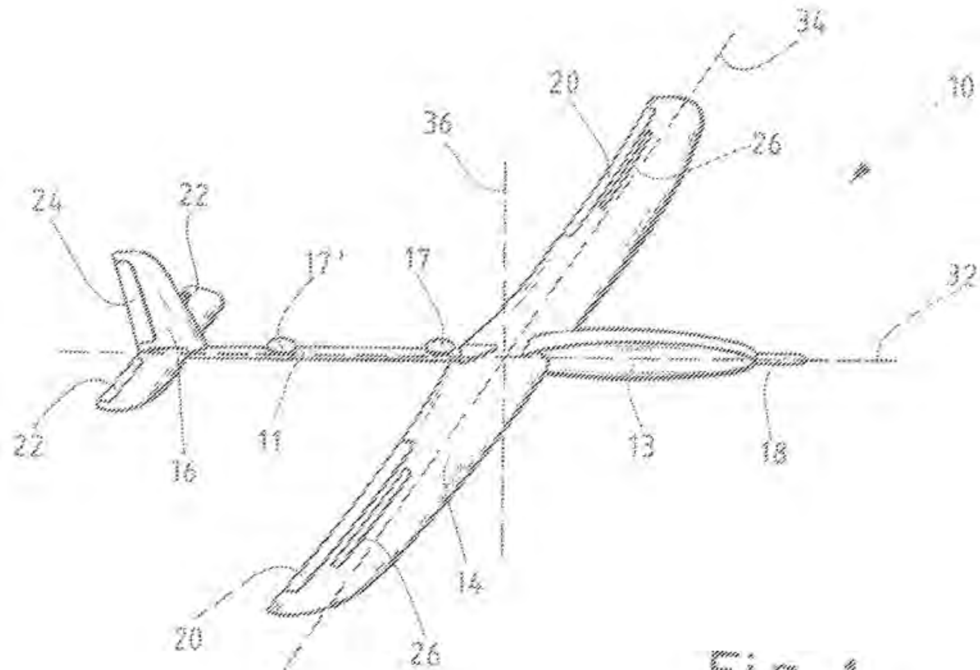


Fig. 1

Brief Description of the Drawings

[0048] The invention is described below, without restricting the general intent of the invention, based on exemplary embodiments, wherein reference is made expressly to the drawings with regard to the disclosure of all details according to the invention that are not explained in greater detail in the text. The drawings show in:

[0049] FIG. **1** schematically a glider according to the invention;

[0050] FIG. **2*a*** schematically the operation of a system according to the invention in a first operation mode; and

[0051] FIG. **2*b*** schematically the operation of a system according to the invention in a second operation mode.

[0052] In the drawings, the same or similar types of elements or respectively corresponding parts are provided with the same reference numbers in order to prevent the item from needing to be reintroduced.

Detailed Description of the Invention

[0053] FIG. **1** shows an exemplary embodiment of a glider **10** for electric power production from wind **50** according to the invention.

[0054] The glider **10** is designed as a fixed wing aircraft comprising a fuselage, a main wing **14**, a tailplane **16** and control surfaces **20**, **22**, **24**. Also depicted in FIG. **1** are the longitudinal axis **32**, the lateral axis **34** and the vertical axis **36**, which meet at the center of gravity of the glider **10** and which constitute the intrinsic coordinate system of the glider **10**.

[0055] In the example shown, the fuselage comprises a tube constructed from fiber reinforced composite material as mechanical backbone **11** between the main wing **14** and the tailplane **16** and a nacelle **13**, which is mounted in front of the main wing **14**.

[0056] The main wing **14** can for instance be constructed from a single wing, as in the embodiment depicted in FIG. **1**. However, alternative designs, for instance with a separate main wing **14** on either side of the fuselage are within the scope of the invention.

[0057] In flight, the glider **10** is maneuvered by control surfaces, which in the exemplary embodiment comprise ailerons **20** at either side of the main wing **14**, as well as elevators **22** and a rudder **24** at the tailplane **16**. The control surfaces **20**, **22**, **24** for instance are hinged surfaces used to induce torque around the principle axes **32**, **34**, **36** of the glider **10** by aerodynamic means.

[0058] Torque around the longitudinal axis **32** is induced by means of the ailerons **20**, which can be or are operated simultaneously and in opposite directions. Here, opposite directions means that when the left aileron is moved upwards with respect to the main wing **14**, the right aileron is moved downwards. By this, lift is enhanced on the right side of the main wing **14** and reduced on the left side of the main wing **14**, causing a torque around the longitudinal axis **32**. The resulting movement of the glider **10**, a rotation around its longitudinal axis **32**, is referred to as rolling.

[0059] A rotation of the glider **10** around its lateral axis **34**, which is referred to as pitching, is achieved by the elevators **22**, which are used to increase or decrease the lift at the tailplane, thereby inducing a torque around the lateral axis **34**.

[0060] The rudder **24** induces rotation of the glider **10** around its vertical axis **36**, which is referred to as yawing.

[0061] In addition to the control surfaces **20**, **22**, **24**, the glider **10** comprises spoilers **26** on either side of the main wing **14**, which can be raised to decrease the lift coefficient and at the same time increase the drag coefficient of the main wing **14**. Further control surfaces at the main wing **14** could be foreseen for affecting the lift coefficient and/or drag coefficient of the main wing **14**. In particular, these could be control surfaces at the leading edge of the main wing **14**, so called slats, and/or at the trailing edge of the main wing **14**, so-called flaps. Similar effects can be achieved with a wing with variable aerodynamic profile, for instance a semi-rigid wing where the curvature of the aerodynamic profile can be varied.

[0062] Additionally or alternatively, air brakes at the fuselage could be foreseen, which increase the drag coefficient of the whole glider **10** without changing the lift coefficient of the main wing **14**.

[0063] The operation of the control surfaces **20**, **22**, **24** is controlled by a control device located in the nacelle **13**, which for instance generates steering signals for moving the control surfaces **20**, **22**, **24** according to an intended flight path or flight pattern **52**, **54**, respectively.

[0064] The intended flight path, to which the flight of the glider **10** is controlled, can be externally set or derived by the control device according to an operation mode of the control device. In particular, the flight path may be controlled and adopted continuously, for instance to account for unsteady conditions of the wind **50**.

[0065] For instance, the control device determines an estimate of the current state of the glider **10** and compares this with a desired state defined by the intended flight path **52**, **54**. In case the estimated state and the desired state differ, the control device determines steering signals for the control surfaces **20**, **22**, **24** taking into account the known flight characteristics of the glider **10**.

[0066] The state or state vector of the glider **10** is a set of parameters containing enough information to describe the momentary flight of the glider **10** and the differential evolution thereof. The state vector of the glider **10** for instance comprises the position of the glider **10** in world coordinates, the velocity vector of the glider **10** relative to the surrounding air and the translational acceleration and rotational velocity in three dimensions each of the glider **10**.

[0067] The state vector is continuously determined from measurement signals of two position sensors **17**, **17'** mounted on the mechanical backbone **11**, an air speed sensor **18** mounted at the tip of the nacelle **13** and an inertia sensor with a three-direction accelerometer and a three-axis gyroscope housed inside the nacelle.

[0068] To limit the influence of measurement uncertainties on the flight of the glider **10**, the control device implements a Kalman filter, more specifically an unscented Kalman filter. In particular, the control device comprises a data storage unit, a data processor unit and appropriate algorithms implemented in hardware or software.

[0069] For production of electric power, the glider **10** is connected to a ground station **40** via a tether **44**, which is attached to or connected with the glider **10** at a connection means, which is preferably arranged close to the centre of gravity of the glider **10**. This way, varying loads on the tether **44** do not significantly impair the balance of the glider **10** in flight.

[0070] At the ground station **40**, excess length of the tether **44** is stored on a reel **42**, which is connected to an electrical machine **46**. The electrical machine **46** is connected to an electricity storage and/or distribution system (not shown) such as a power grid, a transformer station or a large-scale energy reservoir. Those skilled in the art will appreciate that the power storage and/or distribution system can be any device or system capable of receiving electricity from and delivering electricity to the rotating electrical machine.

[0071] The system comprising the glider **10**, the tether **44** and the ground station **40** is alternately operated in a first operation mode for production of electric power, illustrated in FIG. **2a**, and a second operation mode for system recovery, illustrated in FIG. **2b**.

[0072] In the first operation mode, which in particular is an energy production operation mode, the glider **10** is, by means of the control device, controlled to follow a high lift flight pattern indicated by line **52** downwind of the ground station **40**. In the figures, the direction of the wind is indicated by arrow **50**. During crosswind flight, in particular fast crosswind flight, the airfoil or the main wing **14**, respectively, of the glider 10 generates a lift force much larger than required to keep the glider 10 at a given altitude. As a consequence, the glider exerts a pull on the tether **44**, which is correlated to the excess lift force.

[0073] The pull on the tether **44** is used for reeling out the tether **44** from the reel **42** in direction of arrow R, thereby inducing a rotation of the reel **42**. The resulting torque, which in particular depends on the diameter of the reel **42** and the force with which the tether **44** is pulled, is transmitted to the electrical machine **46**, where the mechanical energy is transformed to electric power. Optionally, a gearbox is arranged between the reel 42 and the electrical machine **46**, which is not shown in the figures for reasons of simplicity.

[0074] As long as the tether **44** is reeled out, the glider **10** flies away from the ground station **40**. Thus, the overall length of the tether **44** limits maintaining the first operation mode.

[0075] For recovery of the tether **44**, the glider **10** is, again by means of the control device, controlled to fly towards the ground station **40**. As the glider 10 approaches the ground station **40**, the free length of the tether **44** is shortened and the tether **44** is reeled in onto the reel **42** as indicated by arrow R’ by operating the electrical machine **46** as a motor rather than as a generator. The necessary power for instance is provided or delivered by the electricity storage and/or distribution system.

[0076] In the second operation mode, it is preferred that the pull on the tether **44** is as low as possible in order to minimize power consumption for reeling in the tether 44 and as fast as possible in order to minimize the dead time, i.e. the period of time where no electric power is produced. The glider **10** therefore is controlled to follow a low lift flight pattern **54**, which for instance is a descent or a fast dive of the glider **10** against the wind **50** towards the ground station **40**. However, the low lift flight pattern **54** can also be an approach of the glider **10** towards the ground station **40** without loss in altitude, including a slight gain in altitude.

[0077] If the approach runs slow, for instance because a high lift coefficient of the main wing **14** delays a descent of the glider **10**, the lift could be decreased and/or the drag could be increased by means of the spoilers **26** or the equivalent measures discussed above. This way, the return of the glider **10** towards the ground station **40** can be sped up and the time where the system does not produce electric power is reduced.

[0078] An optimization of the lift and/or drag can also be achieved by modified operation of the ailerons **20**. Instead of anti-parallel operation for rolling the glider **10**, both ailerons **20** in parallel can be moved upwards for decreased lift or downwards for increased lift.

[0079] If the glider has two control surfaces on either side of the main wing **14**, for instance an aileron **20** and an additional flap, drag can be increased without or with almost no change in the lift by moving the ailerons **20** up and the flaps down or vice versa. Here, flap in particular refers to a hinged control surface at the trailing edge of the main wing **14**, i.e. a control surface which is structurally similar to an aileron **20**.

[0080] All named characteristics, including those taken from the drawings alone, and individual characteristics, which are disclosed in combination with other characteristics, are considered alone and in combination as important to the invention. Embodiments according to the invention can be fulfilled through individual characteristics or a combination of several characteristics.

List of References Numbers Appearing in the Accompanying Drawing Figures

- [0081] **10** glider
- [0082] **11** mechanical backbone
- [0083] **13** nacelle
- [0084] **14** main wing
- [0085] **16** tailplane
- [0086] **17**, **17'** position sensor
- [0087] **18** air speed sensor
- [0088] **20** aileron
- [0089] **22** elevator
- [0090] **24** rudder
- [0091] **26** spoiler
- [0092] **32** longitudinal axis
- [0093] **34** lateral axis
- [0094] **36** vertical axis
- [0095] **40** ground station

- [0096] **42** reel
- [0097] **44** tether
- [0098] **46** electrical machine
- [0099] **50** wind
- [0100] **52** high lift flight pattern
- [0101] **54** low lift flight pattern

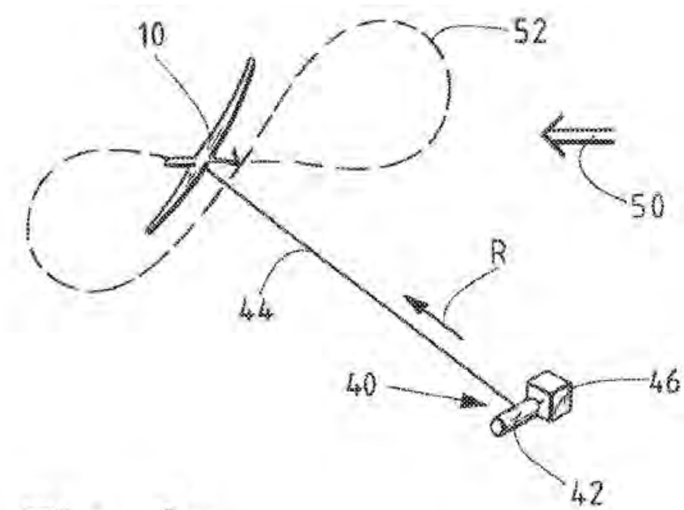


Fig. 2a

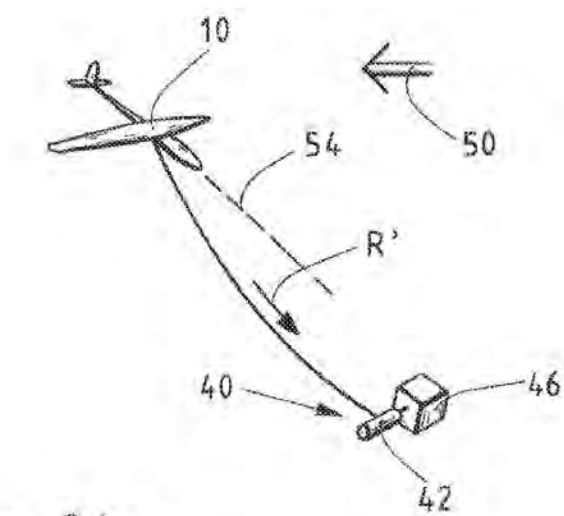


Fig. 2b

Claims

1. A glider for electric power production from wind, said glider comprising an airfoil, onboard steering elements for pitching, rolling and yawing the glider when airborne, a first position sensor for providing a first signal related to an absolute position of the

glider, a second position sensor for providing a signal related to an air speed of the glider and an air speed sensor for providing a signal related to an acceleration of the glider, a control device connected to the steering elements for controlling autonomous flight of the glider based on the signals provided by the first position sensor, the second position sensor and the air speed sensor, and a connector for a tether connecting the glider to a ground-based electrical machine constructed for converting a lift force generated upon exposure of the airfoil to wind and transferred to the ground via the tether into electric power.

2. The glider according to claim **1**, wherein the first position sensor is a GPS sensor.
3. The glider according to claim **2**, wherein the second position sensor is a GPS sensor, and wherein the second position sensor is located on the glider at a given distance relative to the first position sensor.
4. The glider according to claim **1**, wherein the air speed sensor is a pitot tube.
5. The glider according to claim **1**, wherein the air speed sensor is a directional air speed sensor
6. The glider according to claim **5**, wherein the directional air speed sensor is a multichannel pitot tube.
7. The glider according to claim **1**, wherein the glider further comprises an inertia sensor.
8. The glider according to claim **7**, wherein the inertia sensor includes a gyroscope and/or an accelerometer.
9. The glider according to claim **1**, wherein the steering elements comprise at least one aerodynamically active control surface.
10. The glider according to claim **10**, wherein the aerodynamically active control surface is selected from the group consisting of at least one aileron, at least one elevator and at least one rudder.
11. The glider according to claim **1**, wherein the control device comprises a data storage unit for storing data related to flight characteristics of the glider and a data processor unit for deriving control signals for the steering elements based on the stored data

and on the signals provided by the the first position sensor, the second position sensor and the air speed sensor.

12. The glider according to claim **1**, wherein the control device implements a Kalman filter.
13. The glider according to claim **12**, wherein the Kalman filter is an unscented Kalman filter.
14. The glider according to claim **1**, wherein the control device provides for a first operation mode for pulling on a tether connecting the glider with the ground-based electrical machine and wherein the control device provides for a second operation mode for approaching the ground-based electrical machine.
15. The glider according to any claim **1**, wherein the glider comprises at least one aerodynamic control surface for varying a lift coefficient of the airfoil and/or for varying a drag coefficient of the airfoil and/or for varying a drag coefficient of the glider.
16. The glider according to claim **1**, wherein the airfoil comprises a variable aerodynamic profile.
17. A system for electric power production from wind comprising a glider according to claim **1**, a ground-based electrical machine and a tether for connecting the glider with the electrical machine, wherein the electrical machine is configured to convert a lift force generated upon exposure of the airfoil to wind and transferred to the ground via the tether into electrical power.
18. A method for the production of electric power from wind comprising: providing a glider according to claim **1**; exposing the airfoil to wind to generate a lift force during an autonomously controlled flight of the glider; transferring the lift force from the glider to a ground-based electrical machine via a tether; and converting the lift force into electrical power.

Resources

- *US Patent and Trademark Office* (USPTO) — The USPTO provides an oustanding search engine which enables digging through (seemingly) every patent in their office. Proceed with caution — you could easily spend **days** of your time digging through their utterly fascinating files.

- *US 2015/0266574 A1* — A PDF of the original patent as downloaded from the USPTO website, on which this article is based.
- *Ampyx Corporation* from Wikipedia — “Ampyx Power is a Dutch company based in The Hague whose aim is to develop utility-scale airborne wind energy systems…[o]n April 19, 2022 Ampyx applied for, and received, a suspension of payments from the court of The Hague…on May 4 bankruptcy was declared.”

Read the next article in this issue, return to the previous article in this issue or go to the table of contents. A PDF version of this article, or the entire issue, is available upon request.

Stamps That Tell a Story

Could getting airborne help Santa make his appointed rounds?

Each year for more than twenty years Brazil has issued several special airletter sheets for the holiday season. These aerogrammes have different colourful themes, and everyone is encouraged to use them. The 1980 series included one sheetlet where a modern day Santa Claus is delivering his presents via hang glider.

But I also would like to show the side which is more important to the aerophilatelist or stamp collector, the front (which is to say the postal part of it) side.

Because the Christmas holidays arrive at different times around the world, Santa Claus, Saint Nick, der Weihnachtsmann, Sankt Ruprecht or by whichever name he is called in your part of the world, has to work fast, very fast.

So, why not deliver all the presents via glider or hang glider? There is not too much explaining I can do on the subject of Santa, I'm afraid.

This is a custom which originated long before anyone invented the aeroplane or flying machine.

Santa employing some sort of flying machine has been a popular theme for a very long time. (Click any image for more detail)

To all of you it is my hope that we all may experience peace, hope and friendship during this holiday season and throughout the coming year!

Also by the Author

- *[Stamps That Tell a Story: The Series]* — Catch up on your missing instalments of this excellent and informative series of articles presented previously in the New RCSD.

This article first appeared in the January, 2003 issue of Gliding *magazine. Simine Short is an aviation researcher and historian. She has written more than 150 articles on the history of motorless flight and is published in several countries around the world as well as the United States. She is also the editor of the Bungee Cord, the quarterly publication of the Vintage Sailplane Association.*

*Read the **next article** in this issue, return to the **previous article** in this issue or go to the **table of contents**. A PDF version of this article, or the entire issue, is available **upon request**.*

The Trailing Edge

Getting in some practice at Lake Strandefjorden, Norway on January 20th, 2022. (credit: Jo Grini, see text for details.)

So this is The Winter Issue, is it?

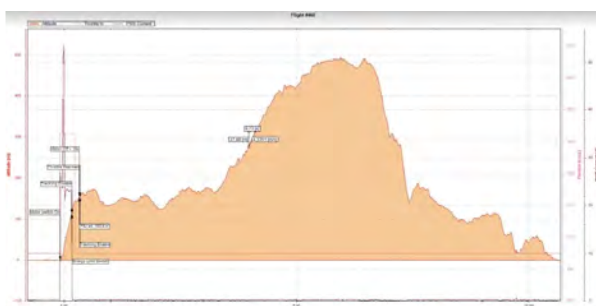
The Ed just grumbled over the pony wall partition something along the lines of:

“so, um, like…y’know…winter edition…okay?”

That was the entirety of his laser-like editorial directive. Good to know. It would have been better to know a month ago but the second best time is about the same time the presses begin to roll for December. Yeah, for sure. Which is **right now**.

Then, like manna from heaven, an *absolutely perfect* image dropped into the laps of those of us responsible for this wrap-up rejoinder. And it comes with a suitably wintry story from Jo Grini of Aurdal, Norway, who took the absolutely magnificent photo for this iteration of *The Trailing Edge*.

The picture is of his 1400g *Liberty F5J X-tail* from CCM out on the frozen Lake Strandefjorden, Norway on January 20, 2022. Jo reports there were “a few strong thermals that day. It was very cold and windy every time they passed.” Jo continued, “here is…more background info logged on that day…it shows that one should still do flying and practice during winter!”



Left: The wind blowing the snow across Lake Strandefjorden makes it look really cold! | Centre: The weather on that day captured by Jo’s weather app. | Right: One of the day’s flight logged with the AerobTec flight logging app. (credit: Jo Grini, click the video or the images for a higher resolution view.)

Well, maybe not mere mortals like us, Jo, but clearly you have proven that nesting indoors in the winter is a choice rather than a necessity, so along as one is suitably equipped. Thank you for sharing this remarkable day with us.

We hope The Ed thinks we’ve been working on this for the entire month, whereas in reality it all came together in the last couple of days. Whew! And in the interest of helping out our fellow co-workers, we just texted them over at the Shop:

```
He’s on the warpath about a ‘Winter Issue’ or some
such. Best be suitably prepared.
```

New in The RCSD Shop

The New RCSD Embroidered Beanie available in five colours. (foreground image: Studio RCSD | background image: Jonathan Knepper)

We’ve been planning the winter edition of *New in The RCSD Shop* for months! And look what we have: the toasty warm ***New RCSD Embroidered Beanie*** . It’s beautiful, very practical and available in your choice of five elegant colors. One size fits most. It’s just what you need for a chilly day on a frozen lake in Norway—or if you just want to look cool while you’re there.

All items in the Shop are made especially for you as soon as you place an order, which is why they are fairly priced and it takes us a bit longer to deliver them to you. Making products on demand instead of in bulk helps reduce overproduction and waste. Everybody wins.

Thank you for making thoughtful purchasing decisions!

Make Sure You Don’t Miss the New Issue

You really don't want to miss the January, 2023 issue of the New RC Soaring Digest when it's out — we always have some exciting things in the works. Make sure you connect with us on *Facebook*, *Instagram*, *Twitter* or *LinkedIn* or subscribe to our *Groups.io* mailing list. Please share RCSD with your friends — we would love to have them as readers, too.

That's it for this month…now get out there and fly!

Resources

- *Liberty* from CCM Model. — "The new *Liberty* model is the implementation of new ideas and technologies into one single unit. The aerodynamic design is the result of collaboration of famous designers.…"
- *AerobTec* — "a company founded by inventive enthusiasts in robotics and drone technology with deep scientific background and many years of experience in these fields. With extensive focus on innovations, inventions and customers, we are creating breakthrough products and solutions…"
- *Lake Strandefjorden* — "Whitefish and perch dominate in Strandefjorden, but there is also some trout. We recommend fishing from boat, but there are accessible areas from land, such as the part of the Fagernes park where the river Nesevla mouths into Strandefjorden…"

Read the previous article or go to the table of contents. A PDF version of this article, or the entire issue, is available upon request.