Why Kites Fly?—A Reply—George Webster

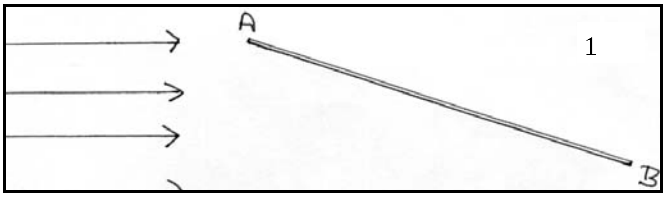
As I hoped, the article on 'Why Kites Fly' generated much more comment than anything else which I've written – some has been published in The Kiteflier, some was letters to me, as well as talk during the flying season. There are three main areas of comment/ criticisms.

1. Some parts of the article were unclear and the text needed to be better linked to the drawings (see 3 below). It was good to get a letter from Ron Moulton (whom I haven't seen all season). He pointed out that the Coanda Effect can actually be seen on Formula One car's rear wings in damp conditions (I haven't looked yet). He still believes Bernoilli to be important. He complains, in a nice way, that I didn't mention the section in his first book as a source on why kites fly. Sorry, but I included only general books which I thought were in print – Pelham and Maxwell Eden. He mentioned that a reprint of his second book (Kites – A Practical Handbook for the Modern Kiteflier by Ron Moulton and Pat Lloyd, second edition 1997) was due out this year. I haven't seen it but am happy to recommend a book, written with great enthusiasm as well as expertise and with those great illustrations by Pat Lloyd.

2. One way and another I've got some new sources. The most interesting is via an email from Stephen Hobbs who mentions the bibliography in his PhD thesis (Hobbs S.E "A Quantitative Study of Kite Performance in Natural Wind with Application to Kite Anemometry" 1986. I should have a chance to look at it quite soon – apart from his references his thesis might be worth a report here. Sorry, Stephen, I haven't contacted you yet – I will do in due course. Other references are: J.W.Loy "Sleds for All Seasons", Kitelines, Summer 1989; J.W. Loy "Why do Kites Fly?", Kitelines, Fall/ Winter 1996; Kitelines, Spring/Summer 1978, the highly critical review of a children's book, supposedly on "Why Kites Fly" has a very impressive looking set of references.

3. My approach was to show the "traditional" view of how kites fly, some of which can be found in kite books, and then present what I believe is the more valid approach. Ron Moulton still thinks that much of the traditional view is important. Peter Cleave (who has written two pieces published here, has also written to me – but we did not get to meet) I think originally misunderstood what I had written but is clearly convinced that to call what I call 'lift' is misleading and that kites are not subject to the same forces as aircraft – and that kite-onautics should be separate from aeronautics. What follows is not a rewrite of the original article – though I admit that I would write it differently. For detail you will have to go back to the original. I am not going to go through the letters point by point. However, in 3.1 below I will set out the basis of how aircraft fly and in 3.2 consider whether kite flight is covered by 3.1.

3.1 Quotation "If any light and flat, or nearly flat, article be projected edge ways in a slightly inclined position, it will rise on the air to until the force exerted is expanded (sic), when the article will descend". The language is dated but it comes from a patent application from Hansom in 1842. Diagram 1 shows a parallel airflow – left to right – and the side view of an inclined plane (wing) A B.



Basic Newtonian theory says that as the airflow strikes AB it will exert a force upwards which is usually called lift. If the lift is greater than the wings weight then AB will stay up. This effect is the same whether the airflow is moving at (say) 20kph against a fixed wing or the wing moves at 20kph into still air.

The amount of lift is much increased from the simple Newtonian idea by the Coanda Effect – which is that, in this example, the wing AB diverts a large flow of air downwards and the downward flowing air exerts an upwards force on the wing. Diagram 2 shows this.

Many books on kites (and books on aerodynamics) explain lift in a different way. Diagram 3 shows an airfoil (i.e. A wing with a

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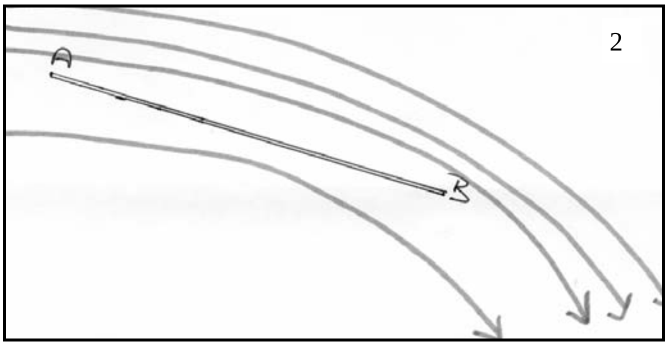
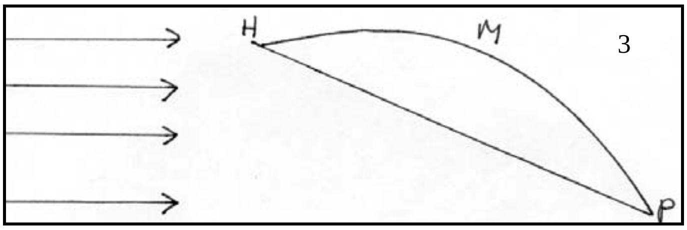
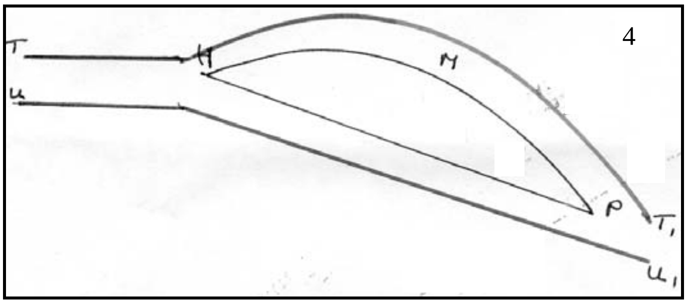
hump or variable thickness).





When this airfoil meets an airflow from left to right we consider what happens to two streams of air; T which follows the top hump of HMP and U which goes straight underneath from H to P.



If we compare the progress of air from T to T1 and U to U1 then the top surface air must have gone faster to end up above U at U1. Now there is a very well established scientific law (Bernoulli theorem) which says that faster speed is associated with lower pressure, therefore the pressure above the wing must be lower than that below. The pressure difference is an upwards force called lift.

There are problems with this 'hump' approach,
A) Why did T and U have to end up above each other at T1 and U1?. The argument says they must: but why? No speed difference, no pressure difference.
B) Why does hump theory require the wing to have the angle of attack (or incline in diagram 1)?
C) Many aircraft have wings much closer to AB than HMP.
D) Aircraft with hump wings can usually fly upside down – but always in such a way that there is a positive angle of attack.
E) There are aircraft wings which are symmetrical on top and bottom surfaces. Think also of modern model aircraft, gliders and paper darts.

For me, the points A to E are enough to persuade me to prefer Newton/ Coanda.

However, even at this very simple level there are two questions to be answered.

F) Why are airfoils (hump) shapes widely found in slow speed aircraft wings? An answer would be that they help to divert airflows downwards (Coanda) and provide stronger lift in this way.
G) What is known from observing airflows over wing surfaces? I tried to give an impression of the evidence in the priginal articles – briefly they show considerable turbulence over the top surface with curious almost 'breaking waves' at the leading edge which might result in forward air movement close to the upper leading edge surface. AB wings at high angles of attack show chaotic airflows above. Even in diagram 4 cases you don't find a smooth airflow. Also when lower pressure above the wing is measured, Bernoulli doesn't assert which cases which, the lower pressure or the faster air speed.

Most importantly, this is a great simpilification in what I have written, which wouldn't be allowable in a book on aeronautics, which is that we have only considered the cross section of the wing, not the plan. We are all aware of differences in wing shape and that e.g Sailplanes have very highaspect ratios. Wings vary widely in their lift charateristics because of their plan shape independantly of cross section, airspeed and angle of attack.

This is mainly for a reason which I have ignored - the existence of vortices which roll up around the wingtips and which travel across their span together with other vertical circular flows - for an explanation see one of the aerodynamics references.

I think that Newtonian force plus the Coanda effect explain one commonly observed aircraft's flight very well. Quote " A helicopter gets lift from it rotor which is a rotating wing. Like all wings this produces lift by directing air downwards with wing shape, cross section and angle of attack all important. Wheter or not we

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have flown by helicopter we all know, because we have seen it on T.V and film, that helicopters produce a strong downdraft - grass flattened, people holding hats etc. Measure all that pressure downwards and you are meassuring lift"

3.2 There is an objection which says that what applies to aircraft doesn't apply to kites, (though I've never seen it in a book). I disagree for two reasons. Firstly science is involved in the search for 'Laws' which explain as wide a range of things possible and it just makes sense to accept the general view that, for example there is a common set of forces which keep up a gliding bird, a sailplane, a fighter, a chuck glider and a kite. Secondly, there are many examples of using the observation of say birds in flight, in one case observation influenced shape and cross section of the wing of a glider which later became the 'first flight' of the Wright Brothers. As is well known the Wrights used kites as the first stage in that development.

Specific points are:

a) Many kites have two dimensions (diagram 1). Cross section wings - this suits the Newton Approach. Nowadays there are many inflatable foil shapes (suits Humps) but also 3D shapes which bear no resemblance to a foil (think Roly the whale).

b) Most kite wings are not rigid (although some are; I recommend polystyrene Tile Box Kites Aerodynamically, so long as the kite takes up a shape and doesn't continually flutter, then that shape can be treated as rigid. Remember that parafoils all stem from Domina Jalbert's realisation that if he could get air pressure to produce the foil shape he wanted, this had advantages over having to construct a rigid shape. Of course parafoils could be cut out of some mythical lightweight rigid material and would still fly.

c) Kites operate at very low wind speed, this is true and is an explanation for the lack of observational analysis. But many model aircraft have comparable airspeeds.

d) kites usually fly at an angle of attack of about 30 degrees - much higher than an aircraft. They are probably stalling in aeronautic terms, but we know that we often can reduce the angle of attack for better performance in high winds - which fits Newton and at very low speeds some kites become gliders.

e) Kite are different because they are controlled not by rigid mount at 90 degrees to the airflow but by a kite line which exerts force at an angle - an angle which can be changed for most kites by movement up or down. This is the most radical difference, but I still think we can use the forces analysed in aeronautics.

If you look in the last issue you will find the two views about 'lift' set out. I am with Roy Martin and Aeronautics.

4 Finally, I have been asked how it helps the kite flier to know how kites fly.

My first answer is that this article is only about the 'lift' part and the original articles try to link that with other aspects of kite design and flying technique. Few of us design new kites, but of course you can make an interesting - beautiful kite without knowing any theory.

What do I get from it? Firstly, Newton/Coanda explains some kites which just did not seem to fit the classic hump approach. Look at a Peter Lynn Black and White cat flying and reconcile it with (diagram 4) T belting quickly over the top to end up just above U at T1 U1. Or look at Anke's Jack in the Box Kite where the lower surface is a series of pyramids. Secondly, it emphasises the importance of a kite being able to adjust to, say, changes in wind speeds by changing its flying angle (in some cases the bridle allows this, sometimes the kite moves up or down the arc at the end of the flying line) - so if you are flying a train the kites need to be able to adjust to local conditions. Last point (for now?)

Peter Lynn has been promising something for some time now on how kites fly - that would be worth reading. Or might I hope you would find it even more worth reading than this?

Why Kites Can Fly—A View—Peter Lynn

Why kites can fly is such a complex question that after a first rush of youthful overconfidence in the '70's, I've despaired of ever finding useful answers- that is, useful in the sense of predicting, for known or intended kites, what effects given changes will have.

But recently I've been thinking that many equally complex problems are understood to a useful extent; quantum effects, relativity, driving in Rome for example- so why not kites?

It's just because kites aren't significant enough to have attracted the necessary talent and energy- no Galileo, no Einstein, no Godel. Unless kites suddenly become as important as say, Brittney Spear's tummy, we're unlikely to benefit from such a one, but maybe us more pedestrian thinkers can make some progress just by thinking about it for longer and by taking very small steps.

With all this sitting on aeroplanes, 10,000 hours of it so far, I've done a lot of (so far rather unproductive) thinking about why kites (more often don't) fly. Taking Occam's razor to this lot now, what do I know?- not necessarily to the standards required for mathematical theorems, but that is soundly based in theory and that does not conflict with known kite behaviour.

1. Single line kites hang in the sky supported by wind with their weight acting to pull their tails towards the ground and point their noses upwards. This is a necessary condition; if the weight force does not act at a point below the point of application of the lift forces, stable single line flying is not possible. This is because when a kite is caused to lean to one side by something (turbulence, a wind shift etc.), it's weight force's misalignment with the lift force can then act to cause the lean to diminish.
2. Any lean to one side will also alter a kite's alignment with the wind, changing the aerodynamic forces acting on it, but aerodynamic forces can only correct a kite's attitude relative to wind direction- and wind direction provides a reference only in the horizontal plane. Up/down can only come from the moment effect of a kite's weight . Until gps and gyro referenced auto pilots become available for kites, weight is the **only** force available to a kite for this purpose.
3. A kite's weight being constant while the aerodynamic forces driving instability are proportional to the square of apparent wind speed, stability becomes more difficult to achieve as wind speed increases: All kites eventually become unstable unless some structural distortion or failure intervenes first.

These things are certain, and obvious enough.

These first three 'laws' of kite stability being satisfied, the key remaining element in kite stability lies in the dynamics of the complex feedback relationships between inertia, the weight force, and aerodynamic forces as a kite recovers from a turbulence or wind direction change induced lean. What can be said with certainty about this process of lean recovery?

4 The rate at which a lean corrects activates aerodynamic drag forces that will slow the rate of correction.
5 The rate at which a lean corrects can activate aerodynamic lift forces that will accelerate the correction – for example, because lift is proportional to the square of wind speed, the advancing wingtip during any lean correction will gain more lift than the receding wingtip loses.
6 Changes in the rate of lean correction will be resisted by inertial forces.

But now here's what may be a new (to me anyway) way to look at things, an hypothesis:

7 If the lean correction proceeds too rapidly, the kite can over-correct into a spin or a series of angular oscillations; called, say, 'rotational' instability.
8 If the lean correction proceeds too slowly, the kite will move sideways so that it's flying line is out of alignment with the wind in the horizontal plane, correction from which can result in a series of destructive lateral oscillations; called, say, 'translational' instability.
9 The kite builder's job therefore is to ensure that the rate of correction from any lean is neither too rapid nor too slow up to the maximum wind speed achievable.

These last three are for me a different way of thinking about kite stability. Previously I've divided instabilities into two main types; 'volatile' instability, in which kites exhibit lateral and angular oscillations of increasing amplitude until a dive or spin results and 'superstability', in which kites progressively lean over and drive off to one side, hanging there for an appreciable time before recovering. By this split, changes that could be made often did not have predictable results because 'volatile' instability and 'superstability' have inextricably overlapping causes and the nett effect of any change is then determined by their relative magnitudes.

Dividing instabilities into 'rotational' and 'translational' instead will be more useful if it allow remedies to be clearly differentiated. Of course it is true that every lean recovery must include at least some element of rotation (angle change) and some of translation (sideways movement) but if 9 above proves to be correct, (and back-reviewing my experiences so far with a wide range of kites lets me hope that it may be), then it should become possible to construct a table which will clearly predict the effect that given changes will have on a kite's flying- which will be a very useful thing indeed.

Hopefully this won't take another 10,000 hours of sitting on aeroplanes!

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