Genesis of *Crosswind Kite Power*

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I plan to touch on several points:

- Stimulation of my interest
- Results of simple and crosswind kites analysis
- Model testing
- Computer simulations
- Funding situation and termination

Four factors stimulated my interest in crosswind kites:

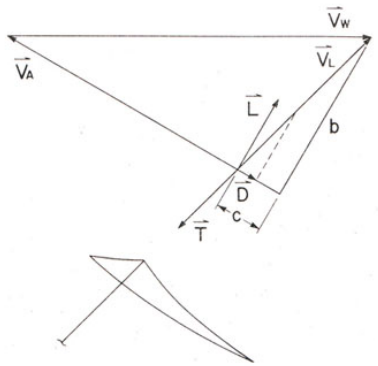
- At LLNL in the mid 1970s, we looked at alternatives to petroleum energy.
- I became aware of the power density of wind in the jet stream and the high energy content of the wind in the upper atmosphere.
- My two sons got interested in model airplanes, so I helped them design, build and fly them.
- This was a vehicle to show my sons elements of a comprehensive project.

When I considered wind power:

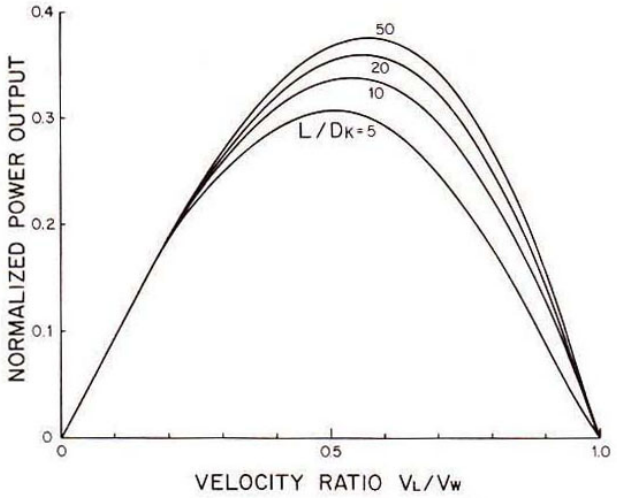
- The jet stream was inspiring, but it moved around too much to be useful.
- Between the altitudes of existing wind turbines and the jet stream there was useful power.
- Kites were the obvious way to support a wind power machine.
- I turned toward analysis of airborne wind power.
- Especially on the wind and kite interaction.

I started by looking at simple kites

- We flew several conventional simple kites.
- Not predictable, reliable, or rugged as needed.
- Increasing the L/D of simple kites did not result in significant increase in power output.



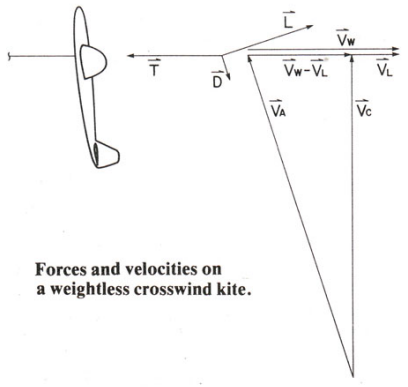
Forces and velocities on a weightless simple kite.



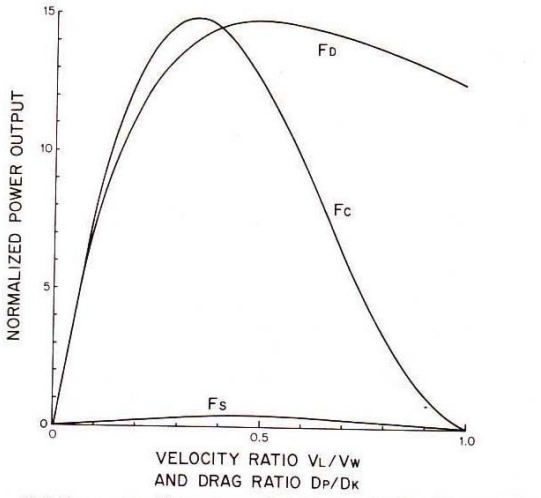
Relative power from a simple kite.

Crosswind kites benefit from high L/D

- For a kite with L/D=10, crosswind flight results in dramatically greater power output.
- Drag on the kite from turbines or pulling a load on the ground produces equal power.



Forces and velocities on a weightless crosswind kite.



Relative power from crosswind kites and simple kites with L/D_K of 10.

High L/D crosswind kites were clearly better than simple kites.

- In the spring of 1976, I visualized an efficient sailplane-like design.
- I first built small balsa models that were hand-controlled by steel piano wire lines attached under the wings.
- There were no moving control surfaces.
- Speed, control, and high line pull with these first kites led me to build slightly larger, more refined designs that my son, David, and I flew extensively.

We flew several with minor variations

David flew this design for the June, 1982 issue of Smithsonian magazine.

These kites were more than fun toys

- Based on my experience with control-line, I judged kite speeds to be 70 to 100 mph.
- Pull on the flying lines was 40 to 60 pounds.
- Fly out of the “power zone” in high winds.
- “Whip” or “lead” the kite in very light winds.
- Control required high concentration.

Experience with hand-controlled kites yielded qualitative conclusions:

- A broad range of wind speeds could be accommodated by varying the flight path.
- Broader wind speed range than windmills.
- High L/D kites require a toss to launch.
- For larger kites I visualized catapults.
- Landing was easily done by flying the kite low and into the wind, so it settles to the ground.

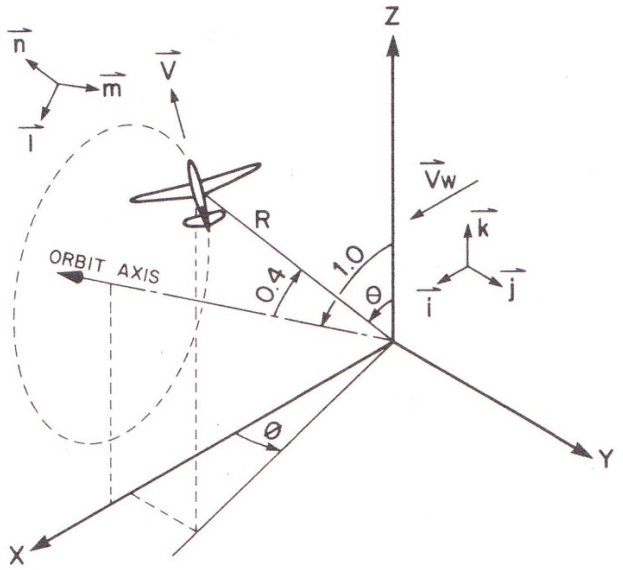
Experiments with Larger Kites

- David built two 5-foot wingspan kites which were tethered to a car with one line.
- He used radio control of elevator and rudder with wing dihedral for best control.
- We launched them by hand-throwing, and landed by flying low, into the wind.
- David got experience with full control.
- He designed them for instrumentation to compare data to calculations.

Simulations were essential to understanding crosswind kite power.

- Built Sol-20; 48Kb memory and tape storage
- No good compiler, so I used a Basic interpreter
- Used 2D polar coordinates with constant R
- Limited calculations to power generation by turbines on a kite
- Pulling a ground load would require 3D calculation with a larger computer

I used polar coordinates with constant R for simulation.



Computer simulations looked promising.

- Should scale nicely to machines much larger than windmills.
- I needed more presentable material to talk with others, so I wrote *Crosswind Kite Power*.
- Selected a conservative, not highly optimistic kite design for presentation.
- *Crosswind Kite Power* was published in the June, 1980 issue of the Journal of Energy.

I planned three sequels to *Crosswind Kite Power*

- Scaling to more optimistic machines limited only by the properties of materials
- Higher altitude operation
- Small scale applications

By1979, funding had dried up.

- About 1976, DOE had sponsored such innovation.
- By 1979, DOE interest had shifted to tower mounted turbines for wind farms.
- Private capital appeared to be exhausted for such ventures.

We laid this project aside.

- In 1980, the boys went off to college.
- I focused on my day job.
- After that I got some calls about the ideas, but no serious interest.
- In 1982, we provided the Smithsonian Magazine material.
- I wrote an article for the 1987 yearbook of the *Encyclopedia Britannica: Kites: New Designs for New Uses.*

Fast forward 30 years.

- In early 2008, I met with Makani a few times and provided my notebooks.
- I am very pleased to see their present success which looks like what I had visualized in *Crosswind Kite Power*.