FEEDBACK

A brief history of kite physics

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A brief history of kite physics

In reply to Margaret Harris's feature on the challenges and opportunities for airborne wind energy ("Harnessing the wind" December 2019, pp26–30).

A long lineage of scientists have explored and developed the kite's physical potential, which is still barely realized

To 18th-century mathematician Leonhard Euler, classic toys embodied deep mathematical physics, and the kite is a prime example of this. Teenage Isaac Newton was a keen kiter before moving on to how apples fall. Since then, a long lineage of scientists have explored and developed the kite's physical potential, which is still barely realized.

The kite became a pioneering atmospheric-research workhorse in the hands of Benjamin Franklin and others. Early in the 19th century, the German-American techno-utopian John Adolphus Etzler declared kites could power civilization. The modern field of airborne wind energy (AWE) could have been born steam-punk style, if only Michael Faraday's new dynamo had been mated to George Pocock's radical kite-drawn buggy.

The 20th-century found the Wright brothers building on George Cayley's work, liberating the kite for free-flight; a world-changing advance. The contemporaneous "golden age of kites" saw highly developed kite-trains routinely reaching the lower stratosphere for meteorological data, altitude records that still stand. Ludwig Wittgenstein started as an early aeronautical engineer and golden-age kite researcher. Aerodynamics slowly transformed into a modern field theory.

Canadian-American inventor Domina Jalbert created the parafoil. New delta kites revealed the benefits of vortex-based lift, and led to modern hang-gliders. AWE concepts proliferated in the 1960s, by pioneers like Hermann Oberth, David Barish, and the husband-and-wife team of Francis and Gertrude Rogallo, who invented the NASA ParaWing – so simple and perfect that, 50 years on, "windsled" geoscience teams routinely cross ice caps, without fuel, revolutionizing long-range polar exploration.

In the 1970s Peter Payne and Charles McCutchen identified fundamental design topologies of AWE systems that inspired Miles Loyd to write the seminal AWE paper and equations (referred to in Harris's feature).

In the last few decades, notable AWE figures include Billy Roeseler, who researched mega-scale AWE at Boeing in the 1960s. By the 1980s Roeseler had invented kite-surfing with his engineer son Cory. Jitrenda Goela was the first university professor in AWE, while astronaut-physicist Wubbo Ockels started the first large-scale academic research programme. Wayne German was particularly visionary in the 1990s, inspiring many. Human-powered flight legend, aviation physicist Paul MacCready, took up AWE at an advanced age.

Naval architect Dave Culp refined minimal-surface ship-kites that were summarily banned from America's Cup racing. Since then, experimental kite-powered or propelled ships increasingly sail the oceans, as portents of a new golden age. Indeed, Airbus has even begun delivering oversize aircraft assemblies by them.

Atmospheric science has converged with anthropogenic climate-change data, making AWE's impact on society more important than ever. Environmental researcher Cristina Archer quantified the vast upper-wind resource right over our heads. Turns out Etzler was right – 20 TW of clean power, now desperately needed by civilization, really is "paradise within reach", as he first put it so long ago.

Basic kite science has also moved along. In the 1990s Harm van Veen identified chaos physics in kite motion. Various scholars reduced kite flight to its fundamental thermodynamics, harmonics, and orbital mechanics, and new AWE engineering paradigms emerged. Numerical calculations of kite dynamics finally incorporated mass and gravity realistically, so simulation closely matched experiment. John W M Bush identified an analogue of quantum-mechanical behaviour in videos of lattice waves in kite trains. Kite networks were reconceived as metamaterials, and were able to process mega-scale lattice wave phonons.

As of 2020, about 100 universities and private ventures are in AWE R&D, putting hundreds of physicists and students to serious work. There have been a dozen major conferences, hundreds of papers and prototypes. Big investors continue to line up, including major energy companies like Shell and the Breakthrough Energy Fund, while the European Union has provided many grants in recent years. SAAB has developed an underwater energy kite, now in initial mass production, while Google has demoed its giant "energy drones" from Hawaii to Norway. Toyota has announced Mothership Project, the most industrially ambitious kite engineering intent yet. AWE is the new Manhattan Project in the sky, with much more to come.

How wonderful to see kites again ready to change the world, in a publication for physicists.

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As a physicist and life-long kite enthusiast, I thoroughly enjoyed Harris's article, which highlights the dichotomy between "lift mode" and "drag mode" kites. The former are far simpler, as all the electrical equipment can be on the ground, but they have to be reeled in when there is no wind. The latter, in contrast, have energy-generation equipment on-board, and need a conductive tether – but they can use their turbines as engines to stay aloft even when the wind has stopped. From a hobbyist's point of view, the lift-mode kites resemble what we call "traction kites" (which are designed to tow surfboards or buggies) while "drag mode" kites look more like model aeroplanes than kites.

The article left me wondering if the AWE community has considered resolving this dichotomy by taking another leaf from the hobby world,

namely the so-called "zero-wind kites". These kites are wonderfully exemplified by the elegant designs of Swiss architect-turned-kite-designer Thomas Horvath, who has a claim to having invented them about 20 years ago (www.horvath.ch). They are designed to fly outdoors, even in the complete absence of wind – tiny, intermittent pulls on the string are all that they need to stay afloat, gliding gracefully in between without net loss of altitude. When there is wind, they will pull on the string and climb like a conventional kite. It occurs to me that a kite design combining elements of a traction kite and a zero-wind kite might retain all the advantages of "lift mode" AWE while dispensing with the need to reel in or land the kite when the wind drops.

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Minority report

In response to Rachel Brazil's feature article "The physics of public opinion" (January pp31–34) where she explains how physicists are trying to predict shifting opinions using the laws that describe the physical world.

I had low expectations when I started Brazil's article, but that quickly changed – I was gripped from the first paragraph. I am amazed that public opinion can be modelled using the Ising model (something I last encountered as a graduate student), and astonished that sociophysics is capable of making such accurate predictions about voting intentions. I wonder if any of the small band of sociophysicists predicted that Boris Johnston would be returned to victory with such a sweeping majority, a surprise given that many saw the election as a second Brexit referendum, and the results of the original had been so close.

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The article provided some insight into events in the UK and has helped me understand why a majority of voters want to leave the EU. It is thought that in the US, Donald Trump's outrageous statements alienated many voters during the last US presidential election campaign. But many others ended up backing him because he had activated their deep-seated prejudices, possibly because of interactions between people within their social networks. I feel that something similar has happened here and, incredibly, as few as 2% more "stubborn agents" on one side of a debate can lead to a tipping point of only 17% – that is, a minority as small as 17% can persuade enough of the other 83% to switch their voting intentions and change the outcome.

The article also provides insight into groupthink, mass hysteria, the group dynamics of a lynch mob, how a despot could gain power even in a democracy (e.g. the rise to power of Adolf Hitler) and it then raises the question of whether we truly have free will. However, perhaps the knowledge provided by sociophysics could help us address these issues. Truly fascinating stuff.

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Sudoku solution

In the December issue we published a Sudoku variant created by reader Michael Metcalf. As a reminder, the rules were that each number from 1 to 16 must appear once in each row, column and 4 × 4 box, as well as in each of the two diagonals (X-sudoku). The solution is provided below.

8	4	2	5	16	1	9	12	7	15	6	13	11	14	10	3
10	6	15	14	4	2	13	8	12	9	11	3	16	1	7	5
7	1	12	3	15	5	6	11	10	8	14	16	2	4	9	13
9	11	16	13	7	14	3	10	4	5	2	1	6	8	15	12
4	7	11	1	9	12	15	16	8	13	5	2	14	3	6	10
14	8	5	16	1	7	11	6	9	3	12	10	15	13	2	4
3	2	6	10	8	4	5	13	14	11	16	15	1	7	12	9
12	13	9	15	10	3	14	2	1	4	7	6	5	11	8	16
13	9	7	4	11	15	2	5	3	1	8	14	12	10	16	6
16	15	3	2	14	9	8	1	6	10	4	12	7	5	13	11
5	14	10	11	6	16	12	3	13	2	15	7	8	9	4	1
1	12	8	6	13	10	4	7	5	16	9	11	3	15	14	2
11	3	1	9	2	6	10	14	16	7	13	8	4	12	5	15
6	5	14	7	3	13	1	15	2	12	10	4	9	16	11	8
2	10	4	8	12	11	16	9	15	14	3	5	13	6	1	7
15	16	13	12	5	8	7	4	11	6	1	9	10	2	3	14

Frying pan to fire

In response to Kate Ravilious' article "Biomass energy: green or dirty" (January pp24–28), in which she investigates whether biomass fuel is as clean as it seems.

I was interested to read in Ravilious' article that biomass power plants are increasing atmospheric carbon dioxide more rapidly than the coal plants they have replaced. In striving to become carbon-neutral we also deceive ourselves about electric cars. There is no doubt that introducing electric vehicles will greatly reduce atmospheric pollution in our towns and cities. However, until all our electricity is generated by nuclear or genuine renewables, the extra demand on the grid must be met by using fossil fuels. At present, switching to electric cars simply transfers the generation of carbon dioxide from the vehicle to gas-fired power stations.

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Correction

The Frontiers article "Clingfish inspires suction cups for underwater robots" (December 2019, p6) should have said "silicone suction cups" and not silicon.