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News & Highlights

After Highflyer Crashes, Airborne Wind Energy Regroups

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In January 2020, a rumor from California in the United States reached researchers and entrepreneurs in Europe, a thriving hub for the small, mostly trans-Atlantic field of engineering research and development called airborne wind energy (AWE): Alphabet, American technology giant Google's parent company, was quietly closing down Makani, the AWE subsidiary it had nurtured into the world's most advanced, visible, and well-funded enterprise designing and building tethered flying machines—kites in AWE parlance—intended ultimately to produce megawatts of wind energy.

Just the summer before, in 2019, the Alameda, CA, USA-based Makani Technologies, supported not only by Alphabet but also Royal Dutch Shell, had attained a headline-grabbing AWE first in offshore wind power [1]. After seven years of both lavish financial support and intense performance pressure from the Google business empire, the startup's most advanced prototype, the M600 kite—actually a large, robotic tethered aircraft with a wingspan rivaling that of a Boeing 737—had demonstrated a series of challenging, autonomous flight maneuvers from a floating base-station off the coast of Norway. With such moves, Makani claimed the potential to generate up to 600 kW of electricity power—the kite's design goal and enough to power approximately 300 American homes—from fast, abundant, offshore winds or other powerful wind currents at heights greater than those reached by the blades of the tallest conventional wind turbines.

Unfortunately, however, the tests also produced disappointments, some of them recurrent flaws noted in earlier onshore flight trials. Perhaps the most sobering mishap was the complete loss of the aircraft, which sank into Norway's coastal waters. In February 2020, the rumor became official announcements, both from Alphabet and from Makani chief executive officer Fort Felker, who wrote in a blog post that "despite strong technical progress, the road to commercialization is longer and riskier than hoped, so from today Makani's time at Alphabet is coming to an end" [2].

Shell pulled its backing as well, and Makani ceased operations completely in September 2020. First, though, the company released into the public domain a collection of intellectual property accrued during its 13 years of existence. With the blessings of its former corporate backers, Makani pledged unfettered use without legal repercussions of its more than 400 patents and patent applications. Also issued were a nearly two-hour documentary film by the company's archivist with frequent and telling visuals of milestones and setbacks [3], and many other videos, internal reports, software, data, and other materials, all anchored by a 1200-page, three-part analysis, *The Energy Kite* [4], written by Makani's engineering staff. "By open-sourcing our work and story," wrote chief engineer and report coauthor Paula Echeverri in a blog post announcing the intellectual property giveaway, "we hope to create tailwinds for the next generation of scientists, inventors, and moonshot takers to tackle the near-impossible" [5].

Makani's abrupt exit triggered a brief sense of crisis within the AWE field [6]. But so far, its collapse seems mainly to have raised questions about how the public and investors will perceive AWE without Makani's charismatic blend of kite-surfing roots, eco-values, flashy engineering, and Alphabet sponsorship to attract media attention. Even with the loss of Makani, several recent developments indicate continued and perhaps rising popularity and national and international support for AWE, said Roland Schmehl, associate professor of aerospace engineering, AWE researcher, and ardent advocate-organizer for the field at the Delft University of Technology (TU Delft) in the Netherlands. Schmehl co-founded and serves on the advisory board of Delft-based AWE company Kitepower, which develops soft-wing kites that, as tethered, reinforced, curved airfoils of flexible fabric, better fit popular notions of what constitutes a kite than rigid-wing drones typically do (Fig. 1).

In late September 2020, a wind technology program of the International Energy Agency (IEA) in Paris, France, convened a virtual meeting of technical experts aimed at establishing the program's first dedicated task to foster broad international research and collaboration on AWE [8]. Notably, this coincided with newly-shown interest in AWE by the US National Renewable Energy Laboratory (NREL) in Golden, CO, USA, which participated in the meeting. Meanwhile, two European AWE kitemakers and AWE's European industry association were recently awarded funding from MegaAWE, a 15 million USD project of the European Commission to advance commercialization of megawatt-scale AWE in northwestern Europe [9]. Schmehl said the AWE field is also anticipating a larger European Union (EU) funding program called Horizon Europe [10] which has signaled an interest in AWE proposals in its funding calls expected in early 2021.

With Makani no longer in business, Ampyx Power of The Hague, Netherlands, one of the kitemakers chosen for MegaAWE funding,

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Fig. 1. In 2013, aerospace engineering graduate students in the Netherlands launch a 25 m^2, experimental, soft-wing energy kite as the tug of a winch on its tether opposes the wind force and helps the kite develop lift. Small flexible kites with simple curved designs familiar from wind sports have scaled up in the past decade to much bigger sizes than the kite pictured here. Those enlarged soft wings have proven suitable for modestly powerful AWE systems for niche uses, such as the first commercially sold system purchased from German company SkySails in November 2020 by the island-nation Mauritius [7]. More complex and difficult to predict or control motions of still larger, stronger soft-wing AWE kites remain subject to further research and testing. Credit: TU Delft, with permission.

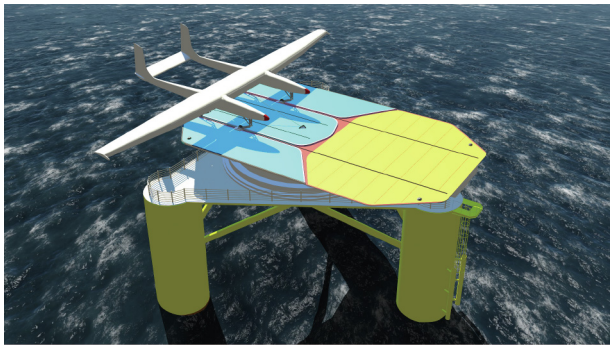

Fig. 2. An artist's illustration shows a megawatt-scale, rigid-wing AWE kite preparing for take-off from an offshore, floating platform to which it is connected by a tether that passes through the triangular port in the platform's deck. A catapult-like assist from the tether launches the kite, after which it flies to operational altitude driven by battery-powered rotors aboard the craft. Propelled only by the force of the wind and gravity once it reaches flight altitude, the kite pulls on its tether to turn a winch below the deck with the unspooling cord, spinning a generator to produce electricity at the platform. After the full length of the tether unspools, the aircraft glides back, unpowered, to the platform as the tether is rewound onto the winch. Landing on the deck, the kite readies to relaunch for another energy production flight. Credit: Ampyx Power, with permission.

now becomes the rigid-wing AWE developer with the highest power, operational prototype in the field. Its newest 150 kW, AP3 drone began light-wind test flights in Spain in December 2020 [11]. Observing that the company released a new, dramatic video to attract investors in December 2020 [12], Schmehl said he suspects Ampyx will replace Makani as AWE's most conspicuous developer.

Ampyx chief executive officer Fabrizio Nastri said that, despite its internet protocol (IP) giveaway, Makani's downfall neither harmed nor helped his firm as the two companies designs are so different. The Makani M600 used an unconventional vertical-take-off-and-landing aircraft that carried its heavy, power-generating turbines on its wing. Both choices are complex and risky for a technology meant to scale up to megawatts, Nastri said. In contrast, Ampyx kites adhere to the near-universal and well-understood aeronautical standard of horizontal take-offs and landings, albeit with mechanical assist to minimize runway size. Rather than carrying generators on board, the Ampyx flyers pull a tether that unreels to spin a generator to produce power at the kite's floating base station (Fig. 2). "We are doing this from a systems engineering point-of-view, using the same standards as the aerospace industry, which is where we get a lot of our engineers," said Nastri. "We are not building ten AP3s with the expectation that we will crash nine and have one—we are designing so they do not crash."

A range of factors, particularly far lower power production than expected, appears to have contributed to Makani's demise. The Makani engineers discuss nine shortcomings of the M600 in the company's parting *The Energy Kite* report [4]. For example, the removal of energy from passing wind by the kite's turbine rotors lessened the effectiveness of control surfaces, such as ailerons and elevators. However, the M600 design did not compensate for this deficit, which limited maneuverability, hampering power production. While in some cases new insights were gained about how energy kites differ from ordinary aircraft, which the authors said may benefit AWE overall, misunderstandings about energy-kite aerodynamics led to prototyping missteps. Rushing ahead to the M600, a much larger kite than Makani had previously built, amplified flaws, the report concludes. A design for a new kite called MX2 that was in progress at Makani when the firm went out of business (and that is also discussed in the report) includes about 60% more wing area, larger control surfaces, and other improvements intended to correct shortcomings that were identified in the M600.

Beyond what took place in Makani's engineering workstations and fabrication shops, other developments likely also played important roles in the company's closure. In global energy markets, the decreasing cost of existing renewable energy and abundant, economical natural gas has driven electricity prices way down, making it much harder for novel, renewable alternatives to thrive [13]. Makani reportedly had not anticipated these price trends, which made it an increasingly unattractive bet for investors [14]. And emerging competition among major companies such as General Electric, Vestas, and Siemens to build conventional but exceptionally large and powerful wind turbines with blades as long as soccer fields will further challenge AWE's viability [15].

Makani was also apparently a special interest of Google founders Larry Page and Sergey Brin—the latter considered especially fond of the pioneering AWE firm—but both stepped down from day-to-day management in late 2019 [16]. This change, it has been suggested, made Makani susceptible to concerns about high losses incurred by Alphabet subsidiaries not directly tied to Google's highly profitable core businesses, such as internet search and advertising [17].

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