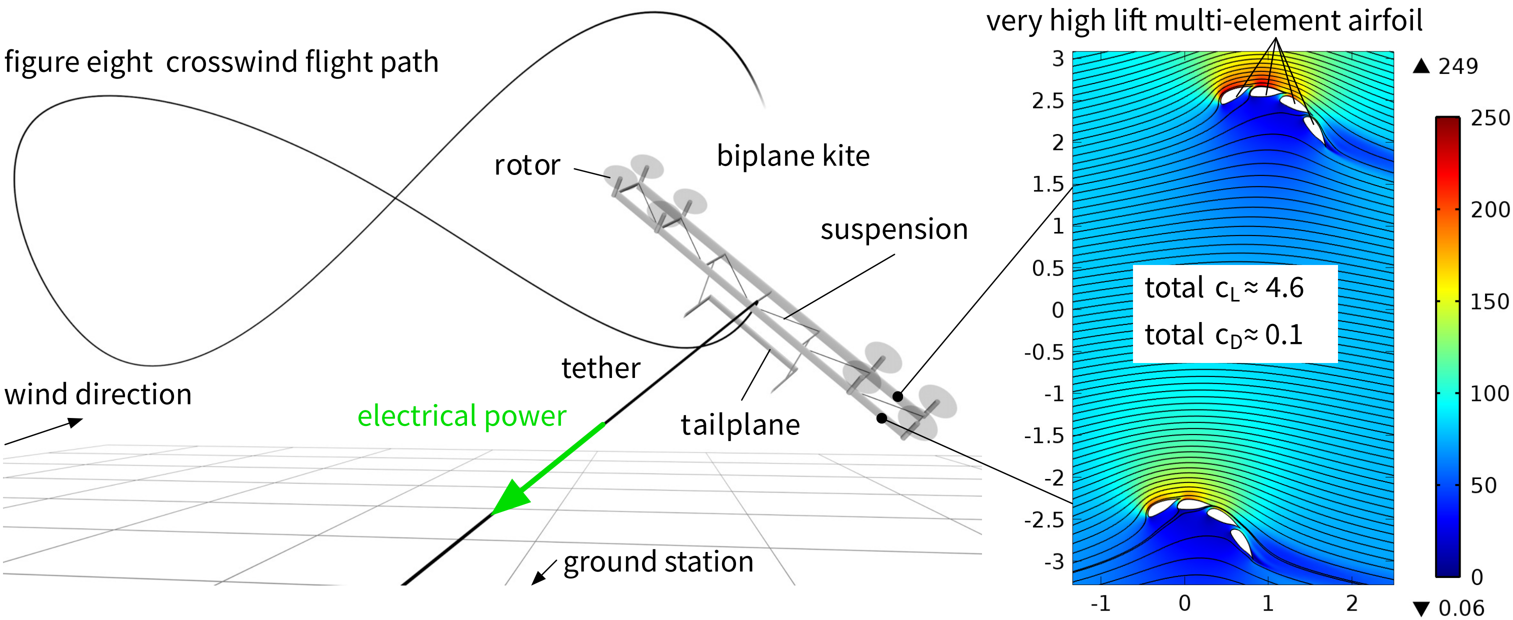

Illustration of "drag power" with biplane kite (left) with a very high-lift multi-element airfoil (right), cf. [3]

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Power Curve and Design Optimization of Drag Power Kites

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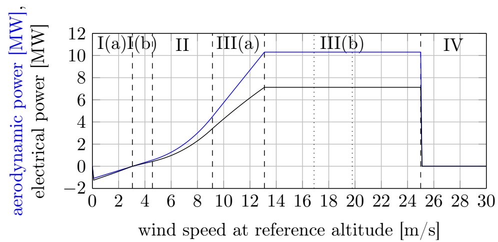
This study considers kites with onboard wind turbines driven by a high airspeed due to crosswind flight ("drag power" [1, 2]). An optimal power curve and an optimal overall power plant design with requirements for a detailed kite design are derived. For that, the model of [3], which extents Loyd's model by an airfoil polar model, a 3D wing model, a tether drag model, a wind field model and an economics model, is further extended by a model for the electrical cables of the tether and their sizing, an actuator disk model for the rotors for crosswind flight in turbine and propeller mode as well as for hovering, and a drivetrain model (efficiencies, masses, costs). A biplane kite with a very high lift multi-element airfoil is considered, as it is found as optimal in [3].

The power curve with all meaningful regions and required actuations (rotor drag coefficient/induction factor, lift coefficient, actuated drag via air brakes or sideslipping) is derived. With a genetic algorithm, all free design parameters are optimized and numerous parameter studies are performed. One result is that a 40 m wingspan biplane kite with a wing area of 80 m^2, a lift coefficient of 4 and a tether length of 370 m achieves a nominal electrical power of 7 MW, i.e. it has a power density of 90kW/ ^{2}. Moreover, the kite power plant has a maximum allowed cost of 5.5 Mio.USD to achieve a LCOE of 0.05 USD/kWh and the kite has a maximum allowed wing mass density of 140 kg/m^2. A biplane kite is expected to be superior to a monoplane kite with respect to its ability to sustain the very high wing loading of 1600 kg/m^2 caused by the high lift coefficient.

First simple component verifications have been conducted, but further verifications are planned for both, component level and system level. In this talk, the derivation and underlying assumptions of the kite model are presented and key results of the parameter studies are discussed.



Optimal power curve for a 40 m wingspan biplane kite.

References:

*[1] M. Loyd: Crosswind Kite Power. Journal of Energy **4**(3), 106-111 (1980)*

[2] U. Ahrens, M. Diehl, R. Schmehl (Eds): Airborne Wind Energy. Berlin-Heidelberg, Springer, 2013

[3] F. Bauer, R. M. Kennel, C. M. Hackl, F. Campagnolo, M. Patt, R. Schmehl: Drag power kite with very high lift coefficient. Submitted for publication in Renewable Energy (Elsevier), 2017. Available from http://www.eal.ei.tum.de/en/research/projects/research-bauer/