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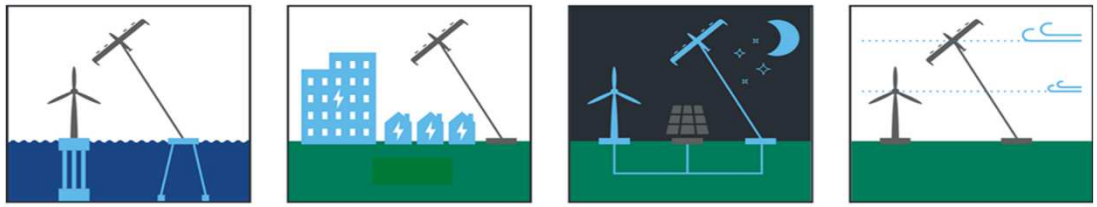
Topical Expert Meeting TEM#102
Airborne Wind Energy



Session 2D:
Common Design Tools, Simulations, and Reference Models

23-24 September 2020

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Overview of topics

Design/Simulation Tools

- Summary of available tools
- Categorization of tools (e.g., open-source? level of fidelity? Experimentally validated?)

Reference Models

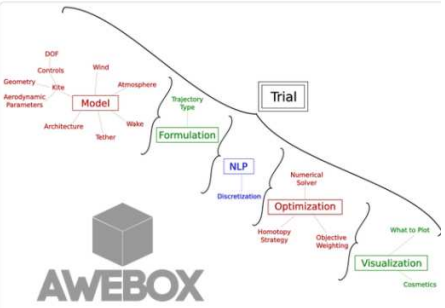
- Multi-MW reference model (based on Ampyx AP4) – Delft/ETH/DTU
- Discussion of possible reference model efforts around Makani design

Openly Available Flight Test Results

- Summary of organizations that have released flight test results
- Categorization of test results (lab-scale/small-scale/full-scale? test duration? extent of available data?)

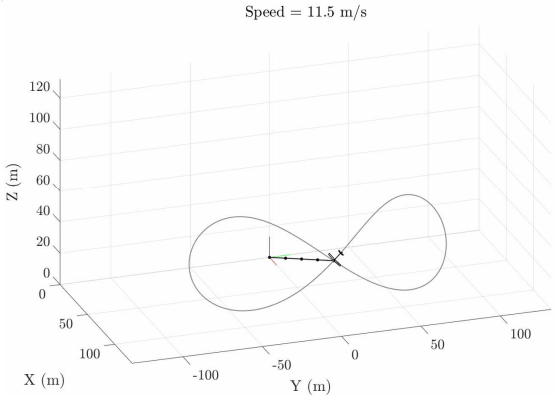
Design and Simulation Tools

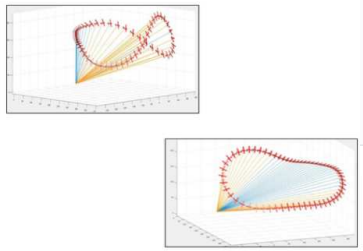
Dozens of tools, dozens of organizations, significant overlap, and also some gaps…



AWEBOX

A Python toolbox for modelling and optimal control of multiple-kite systems for airborne wind energy harvesting.



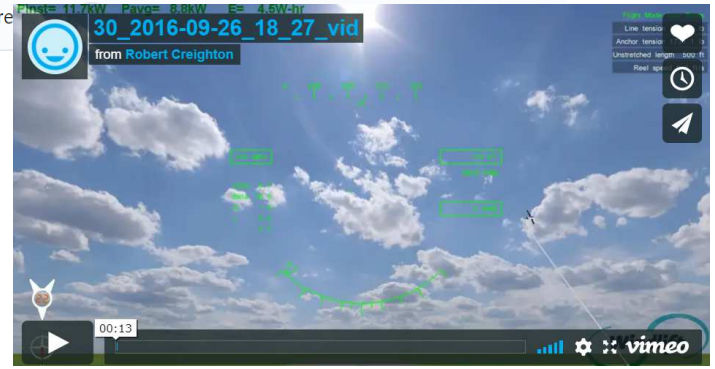


OPENAWE

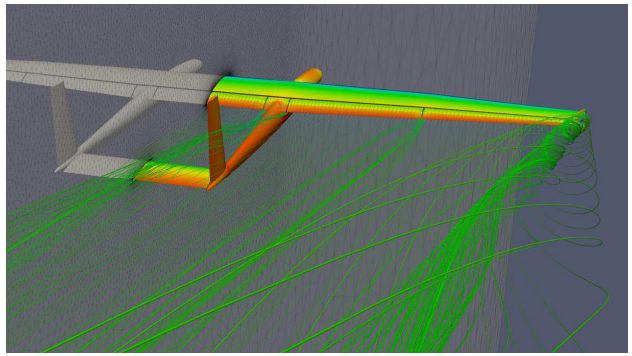
A Matlab and Octave library for modelling and optimization the operation of airborne wind energy systems.

google / makani

Code Pull re



A Vortex Step Method for Nonlinear Airfoil Polar Data as Implemented in KiteAeroDyn



Design and Simulation Tools

Tool	Brief description	Type of AWE system?	Availability ?	Validation
Makani open-source code	Full control code and dynamic simulation	Fly-gen, rigid wing	Public, open-source	Experimentally validated at large scale
FreeKiteSim (Uwe Fechner)	Simulation	Ground-gen	Public, open-source	Unknown
AWEBOX	Modeling and optimal control	Multiple-kite systems	Public, open-source	Unknown
AWE-ERA5	Resource characterization	Any	Public, open-source	Based on ERA5 data
MEM4PY	Structural analysis (FEA)	Soft kites	Public, open-source	Unknown
OpenAWE	Crosswind flight trajectory optimization	Ground-gen	Public, open-source	Unknown
KiteFAST (NREL/Makani)	Simulation	Fly-gen, rigid wing	Public, open-source	Unknown
Windlift/FS-One Simulator	Flight simulator	Fly-gen, rigid wing	Not yet publically released	Validated against initial flight test data
NC State tethered energy flight simulator	Flight simulator (including closed-loop control code)	Any rigid wing system (including tethered undersea kites)	Not yet publically released	Lab-scale validations performed

Design and Simulation Tools

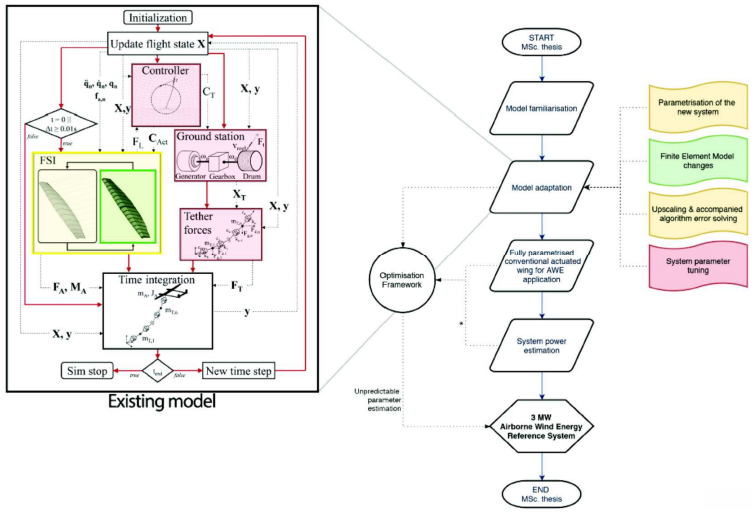
Key questions for discussion:

- Are the aforementioned tools (and researchers developing those tools) duplicating efforts?
- Should the international AWE community establish a working group for model/optimization tool development?
- What opportunities exist for academic teams to validate their tools against larger-scale experimental prototype data (this has perhaps been made significantly easier with Makani's release of flight test data)?

Reference Model Development

Delft/ETH-Zurich/DTU
Multi-Megawatt Reference Model:

- Part 1: System definition
  - Based off of the Ampyx AP4
  - Ground-gen, rigid wing system
  - 3.8 MW cycle-averaged power output
  - Wing area = 150 m^2
- Part 2: Tailored simulation and optimization framework



D. Eijkelhof, "Design and Optimisation Framework of a Multi-MW Airborne Wind Energy Reference System," TU Delft Aerospace Engineering, 2019.

Reference Model Development

Discussion topics:

- What efforts are being undertaken (particularly in North America) to create a fly-gen reference model based (perhaps) off the Makani M600?
- Should we create a multi-institution working group (academia + industry) for reference model development?

Flight Test Results

- Makani has released flight logs for every M600 flight
- TU Delft is compiling 6 years of test data (2010-2015) on a 20 kW kite power system

- **Discussion questions**:
  - Should we orchestrate an effort/working group aimed at validating the suite of simulation tools (slide 3) against these flight test data (and how much of that has been done?)?
  - Are the system parameters for the above-referenced designs readily available so that the above is possible?
  - Should we build a working group focused on building AWE into a complete energy model (e.g., HOMER, LUT “Internet of Energy” model)?