## Introduction to 3rd Scientific Advisory Board (SAB) Meeting of the ERC Project HIGHWIND

## Moritz Diehl Freiburg, June 12, 2015









- HIGHWIND Project Update
- Scientific Advisory Board (SAB)
- Overview of the Day

## **European Research Council Project 2011-2016**



#### Simulation, Optimization, and Control of High Altitude Wind Power Generators

Aim: Guide the development of high altitude wind power, focus on *modeling, optimization, and control*, plus small scale experiments.



## Four Work Packages of HIGHWIND

- WP1 Mathematical Modeling of Airfoil and Tether
- WP2 Optimal Control and Stability Optimization
- WP3 Embedded Control
- WP4 Small Scale Experiments

## The ERC HIGHWIND Team at last SAB 2013 in Leuven



Prof. Moritz Diehl principal investigator



Dr. Sébastien Gros Now Prof. at Chalmers



Prof. Jan Swevers control systems



Dr. Andrew Wagner System architect



Prof. Dirk Vandepitte mechanical design



**Greg Horn modelling and optimal control software** 



Prof. Johan Meyers now also ERC grantee



Joris Gillis stability optimization



Kurt Geebelen Hardware design



Mario Zanon predictive control



Milan Vukov embedded optimization

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## The ERC HIGHWIND Team now



Prof. Moritz Diehl principal investigator



Dr. Jörg Fischer Control Engineer



Thorbjörn Jörger Technical Engineer



Dr. Michael Erhard (25%) MPC of SkySails System



Mario Zanon predictive control



Greg Horn (on leave) optimal control software



Jonas Koenemann model predictive control



Adrian Bürger (25%) Estimation Software

#### + very active bachelor, master and job students



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## **HIGHWIND SAB Members**

- **Stephan Brabeck**, CTO of SkySails, Germany. SkySails is a leading company on ship propulsion with towing kites with interest in electricity generation
- **Damon Vander Lind**, Lead Engineer of Makani, a division of Google [x] building Airborne Wind Turbines

not present at this SAB:

- Prof. Dr. Florian Holzapfel, Head of the Institute of Flight System Dynamics, TU Munich, one of Europe's leading groups on flight dynamics and UAV control
- Dr. Chris Spruce, senior specialist at VESTAS, one of the world's leading wind power companies, currently in a joint project with Mitsubishi

## Aims of Scientific Advisory Board (SAB) Meeting

#### Aims

- critically evaluate the performance of the HIGHWIND team
- give advice for improvements
- recommend synergies and contacts

#### Questions to SAB

- what are the strengths, what are the weaknesses of the team ?
- what opportunities and what risks do you see for the project ?



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8:00 Moritz Diehl: Welcome and Introduction
8:15 Thorbjörn Jörger: Highwind Hardware
8:45 Elias Rosch and Julian Reimer: Communication and Visualization
8:55 Maximilian Ernestus and Fabian Girrbach: Flight Software
9:05 Joanna Greulich and Ben Schleusener: Flight Hardware
9:15 Jörg Fischer: Flight control architecture of the half-wing setup
9:35 Johanna Becker and Stephan Christian: Flight Simulations of the half-wing setup

9:45 Coffee Break

10:15 Jesus Lago Garcia, with Adrian Bürger, Florian Messerer and Michael Erhard: State and parameter estimation of the kite system of Skysails
10:30 Jonas Koenemann: NMPC of the carousel-setup with flying ball
11:00 Ernesto Denicia: Control implementations on the HIGHWIND carousel
11:30 Mario Zanon: Control of Dual-Airfoil AWE Systems with NMPC and MHE

## **Program Around Noon**

12:15 Damon Vander Lind (HS 026): Developing a 600 kW Airborne Wind Turbine13:00 Lunch in "Solar Info Center"14:30 Experimental demonstration in Hangar 074

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# 15:30 Closed Door Meeting of the SAB with Young Researchers16:00 Closed Door Meeting of the SAB / Short Break16:15 Feedback by the SAB

17:00 Good-Bye-Reception for all attendants

## **PREPARATION OF FEEDBACK SESSION**

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## Moritz' Notes from the first and second SABs (2012, 2013)

- try to find or appoint a leading "system engineer" in the hardware team for developing the outdoors carousel and 2m-plane (Thorbjörn Jörger)
- use additional sensors for outdoors such as two-hole-pitot-tube and GPS (with raw satellite data, fused via MHE)
- keep large scale simulation studies (PhD Greg Horn), including CFD flow interaction.
- focus hardware development on single airfoil, do not loose focus
- conducting tether vs. pure dyneema: assess development effort for both systems. If conducting, try to get tether in cooperation with other AWE researchers.
- keep MHE algorithms as an important research line (PhD Milan Vukov)
- propeller on board is an easy and recommended way to have more flexibility for flight experiments.
- GPS raw data DGPS could be used
- Find way to tackle sensor synchonization issues
- Implement "watchdog technology" to make MPC failproof with "back-off" controller

## **Questions to SAB**

(1) On the small-scale experimental flight control side, what next setups would you recommend? In particular, is there anything in the following list that shall be dropped or modified:

- half-wing foam plane control
- ball control
- foam plane (Cularis) on a tether
- acrobatic plane (Stingray) on a tether
- other concepts ?

(2) On the sensor side, are there any crucial sensors missing?

(3) For external cooperations, do you have any other ideas extending the current ones on modelling and optimal control with AmpyxPower, Makani, and SkySails?

(4) General impression of what are the strengths, and what are the weaknesses of the team?

(5) What would you see as the three most important achievements of the project so far?

(6) Are there some missed opportunities? For example, are there important topics in AWE optimization and control that are not given enough attention by the project team despite the fact that it would be qualified to address them?

## **More Specific Questions to SAB**

- Should we stop doing experiments ?
- Should we use experiments for training purposes only?
- Should we try to fully team up with an experimentally more advanced partner ?
- Do you still recommend that we go outdoors soon ?
- Do we need a van for shelter and transport of the trailer ?
- Should we create a spin-off e.g. related to consulting and software for optimization, estimation and control ?

## Locations of Meeting, Chair, Lab-Room, and Hangar 074



