AWESCO

Airborne Wind Energy

System Modelling, Control & Optimisation

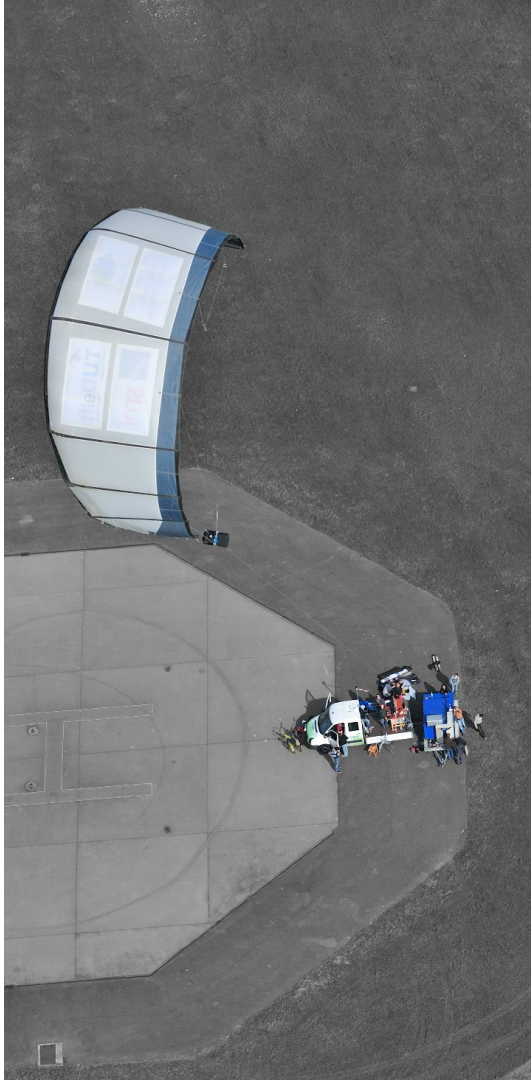
Internal Research Review

University of Freiburg

2 February 2016

Outline

- Societal context & mission statement
- Technology key features
- R&D activities until now
- AWESCO short sketch



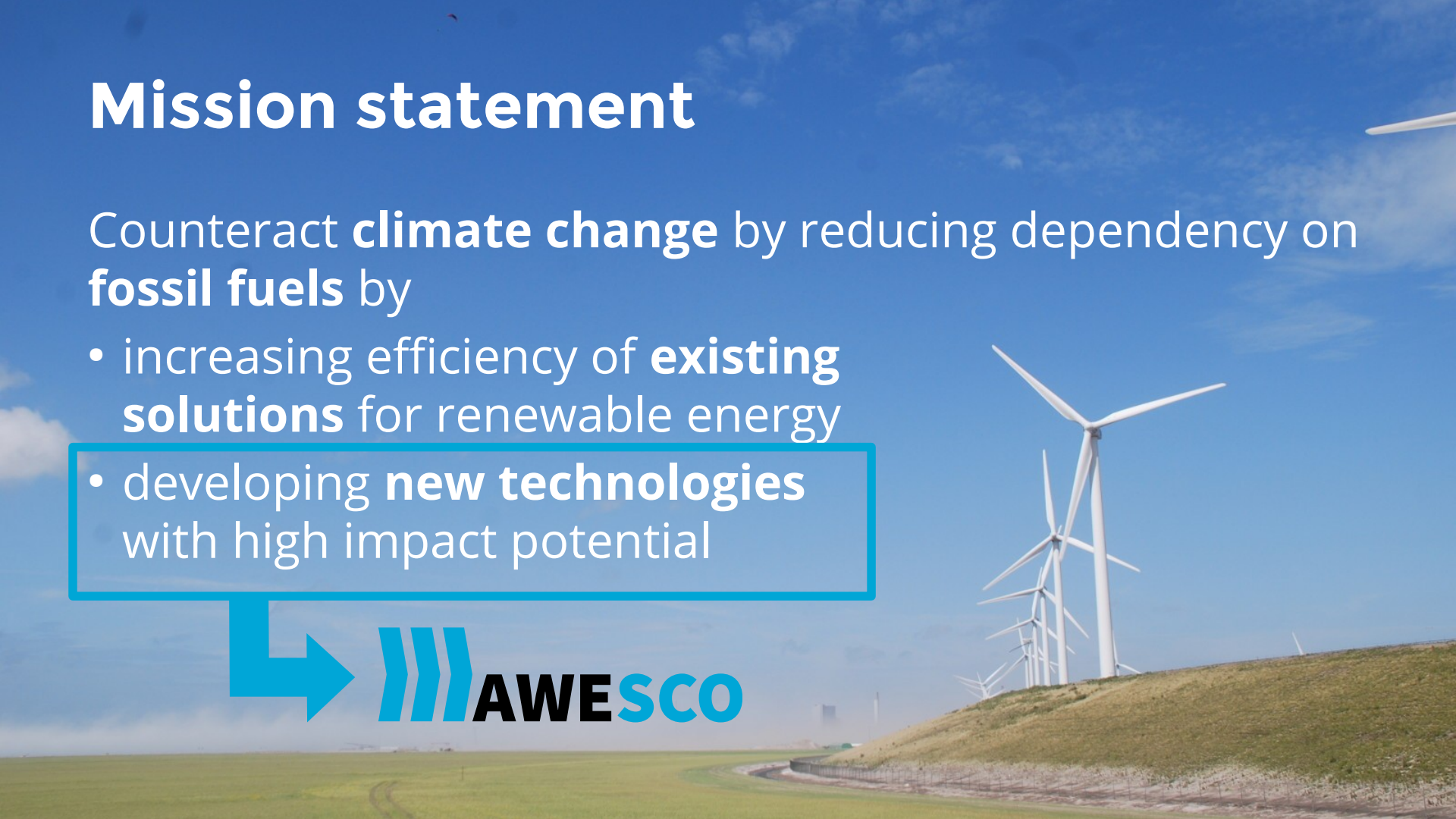
Societal Context

No challenge poses a greater threat to future generations than climate change – Barack Obama

Mission statement

Counteract **climate change** by reducing dependency on **fossil fuels** by

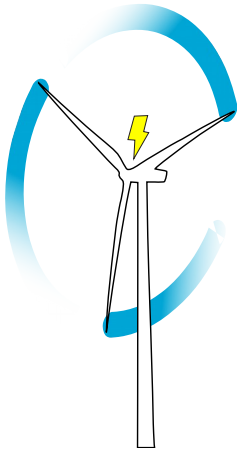
- increasing efficiency of **existing solutions** for renewable energy
- developing **new technologies** with high impact potential



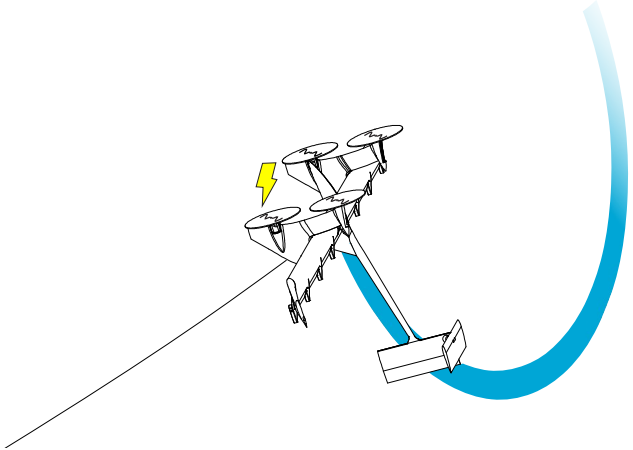

Bill Gates
(Financial Times, 25 June 2015)
High-Altitude Wind Energy
Could be the “magic bullet”.


Wubbo Ockels
(1946 - 2014)
Dutch astronaut & pioneer
of airborne wind energy

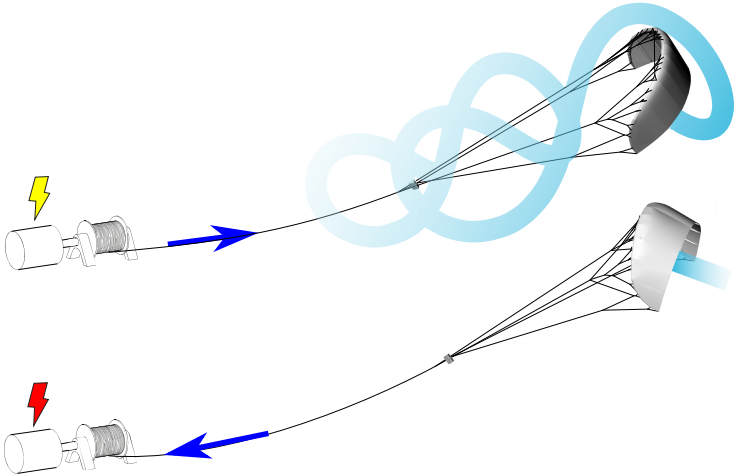
Fundamental concepts



Wind turbine



Airborne Wind Turbine
Makani Power / Google



Pumping Kite Power System
Most others developers

Key aspects

- Consumes significantly less material
- Highly adjustable to wind resource
- Access to high-altitude wind
- Increased mobility

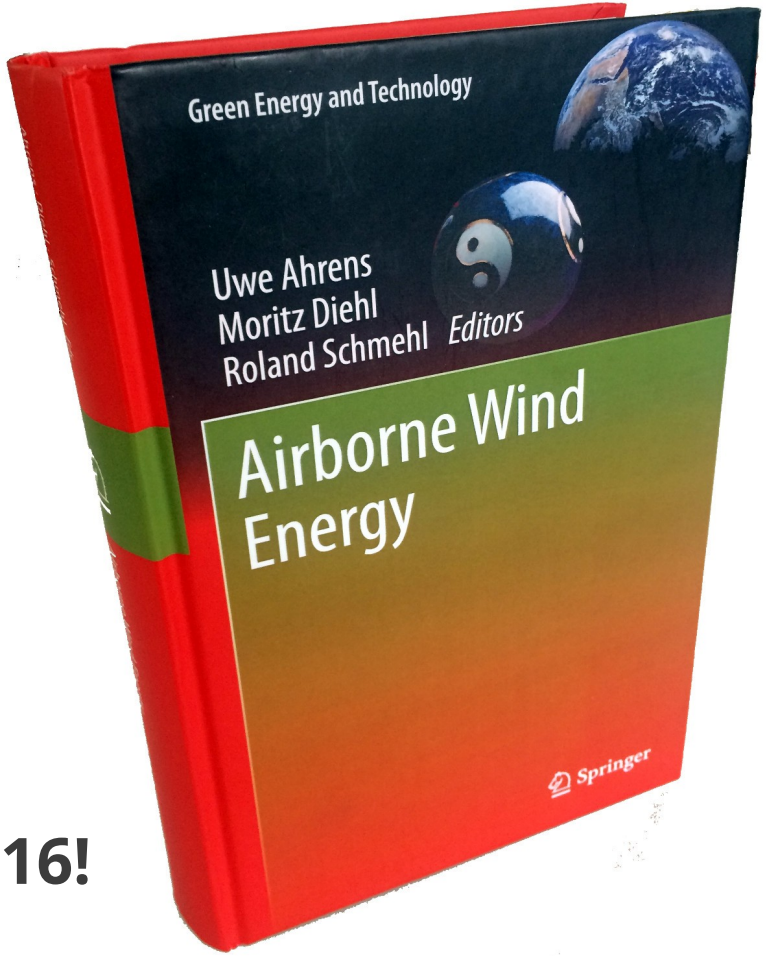
- More complex than turbines
- Requires reliable & robust control
- Depends on high-performance materials
- Need to revise current regulatory framework

AWE textbook 2013

- First textbook on AWE
- Published 2013 with Springer
- 35 peer-reviewed chapters
- 611 pages
- 45234 chapter downloads

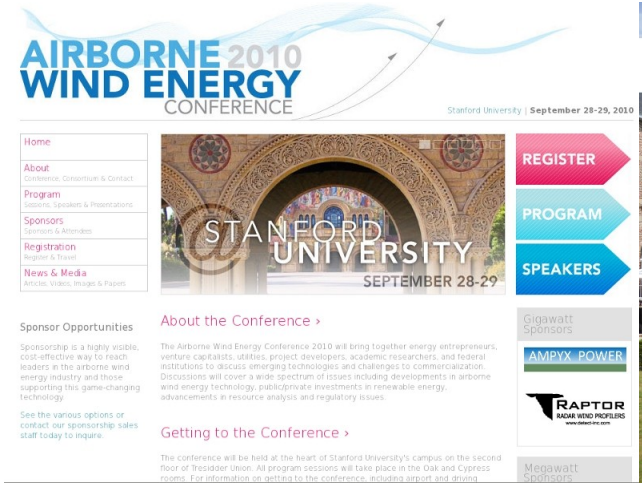
→ High-impact publication

→ Second book in late **spring 2016!**



Airborne Wind Energy Conferences

Stanford (2010)



Leuven (2011)

Berlin (2013)

AWEC 2015 in Delft

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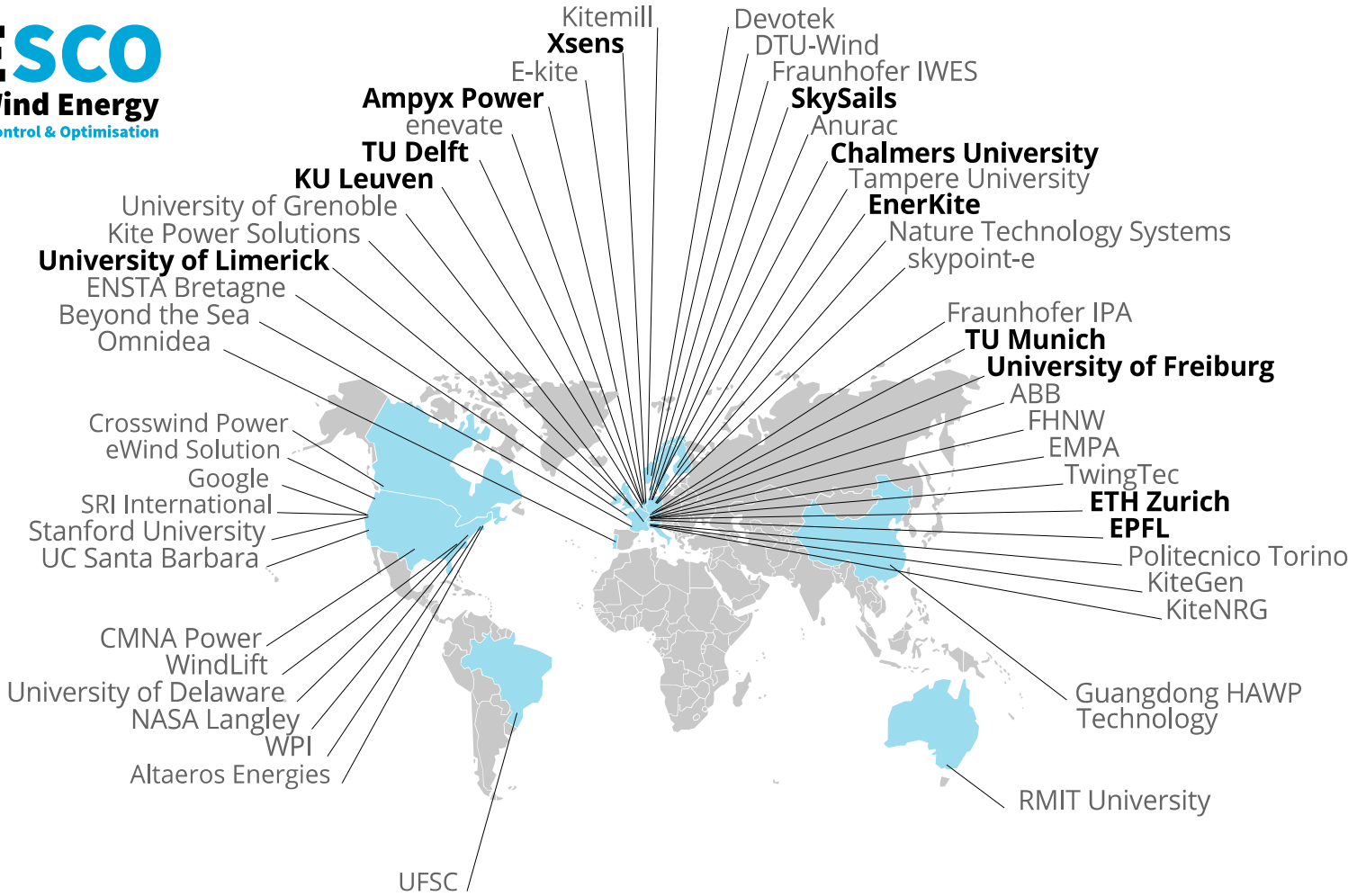
System Modelling, Control & Optimisation



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Airborne Wind Energy
System Modelling, Control & Optimisation

- Marie Skłodowska-Curie European Training Network
- 4 work packages focussing on scientific challenges:
  - **Modelling and Simulation** (WP lead: **TUD**)
  - **System Design and Optimisation** (WP lead: **ALU-FR**)
  - **Sensors and Estimation** (WP lead: **Xsens**)
  - **Control Systems** (WP lead: **TUM**)

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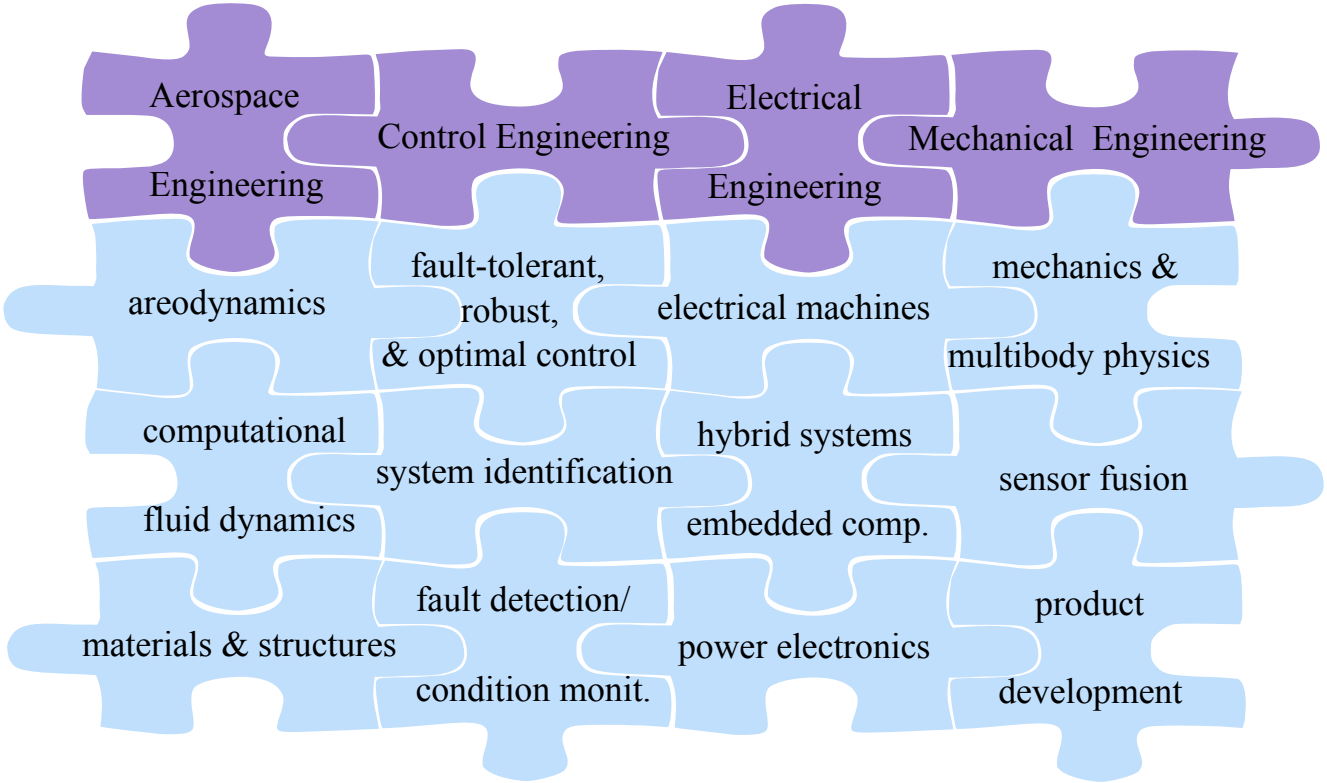
System Modelling, Control & Optimisation



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- **Not covered are**
  - Material research
  - Certification
  - Regulations
  - Environmental impact

→ For other research project

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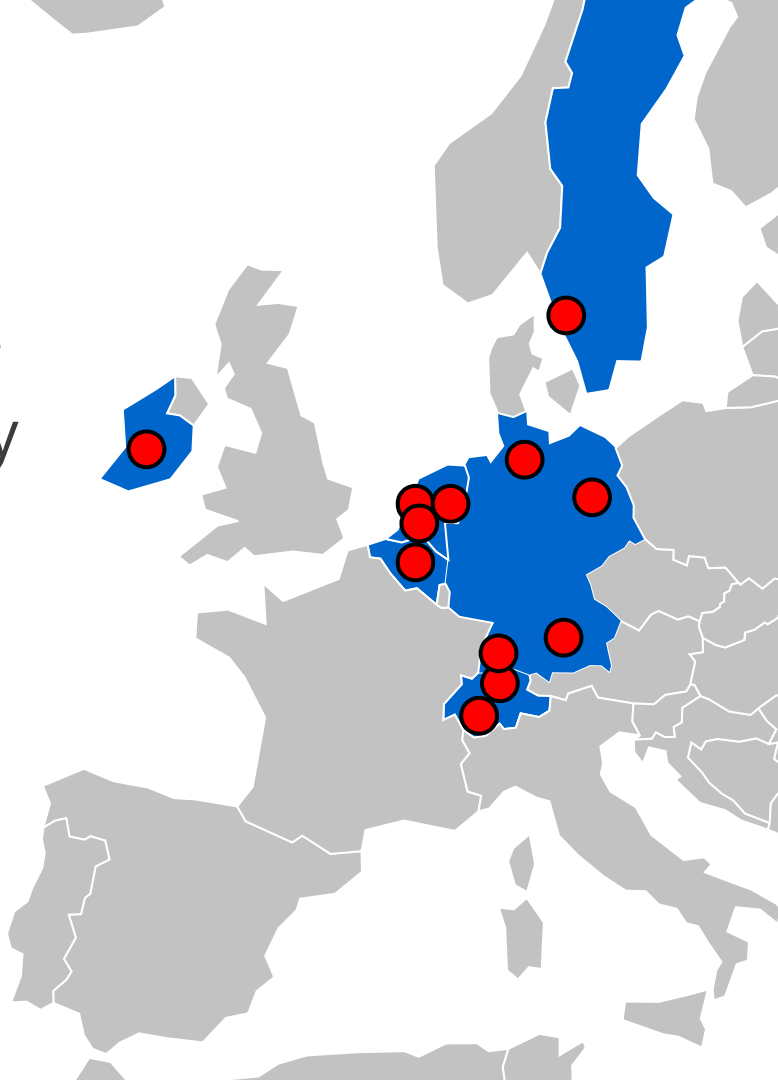
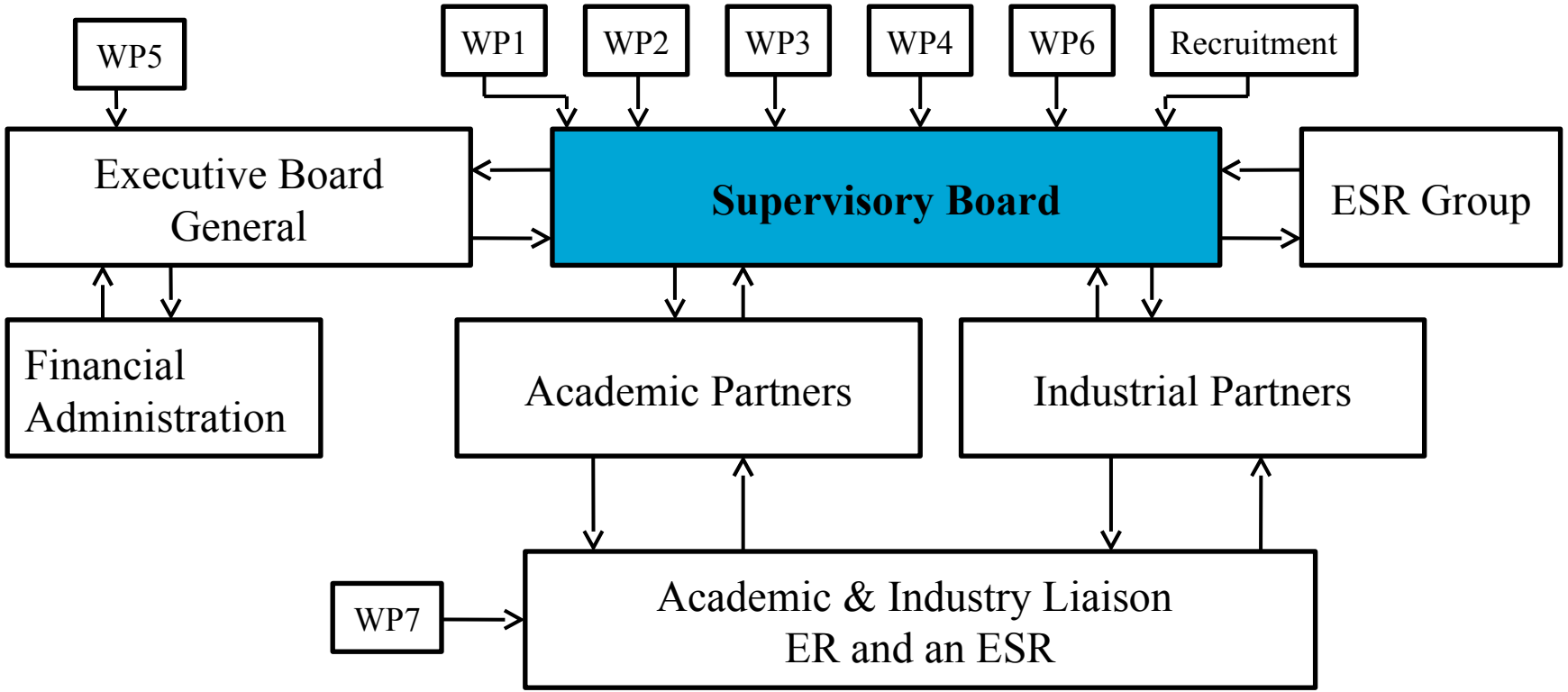
- 14 PhD projects, all contributing to relevant questions of industry
- 10 EU-funded partners
- 2 CH-funded partners
- 3.4 M€ total budget



Management Structure



Associated Partners

- **Fraunhofer IWES** (Bremerhaven & Kassel)
- **Fraunhofer IPA** (Stuttgart)
- **Google / Makani Power** (Mountain View & Alameda)
- **Flysurfer** (Marquartstein)

Conclusions

FUTURE

Pumping Kite Power System

PRESENT

Nuon & Eneco 1.5 MW Wind Turbines

PAST

E.ON 550 MW Coal Power Plant

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Introduction Round

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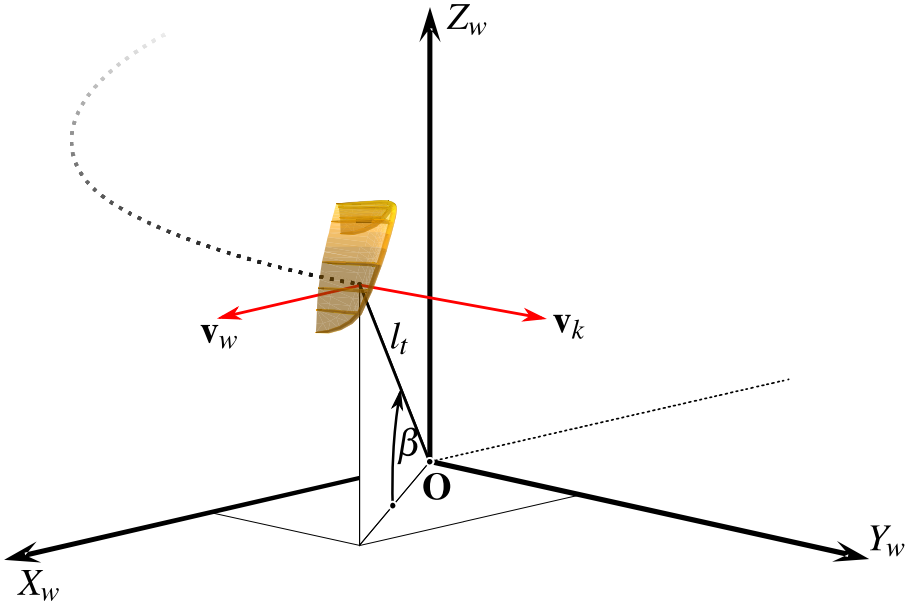
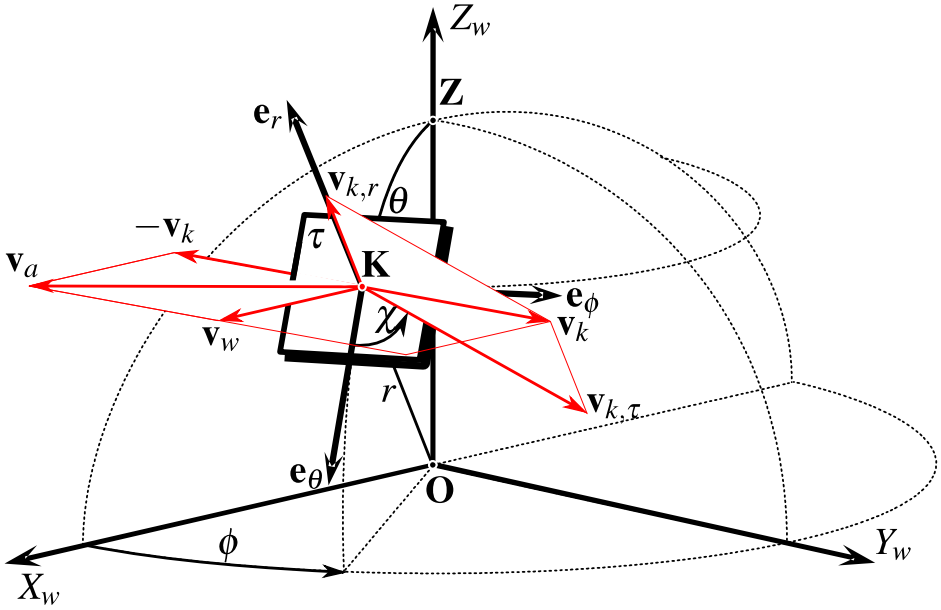
Modelling and Simulation

Work Package 1

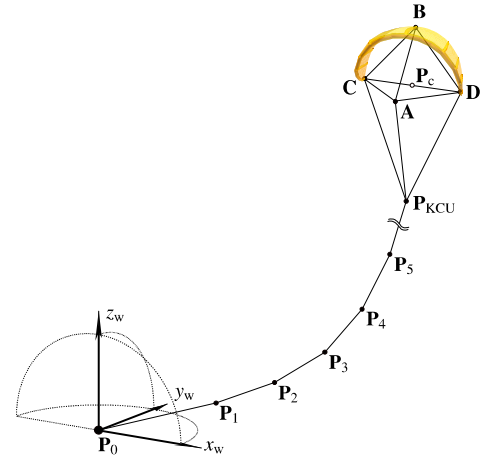
Quasi-steady system model

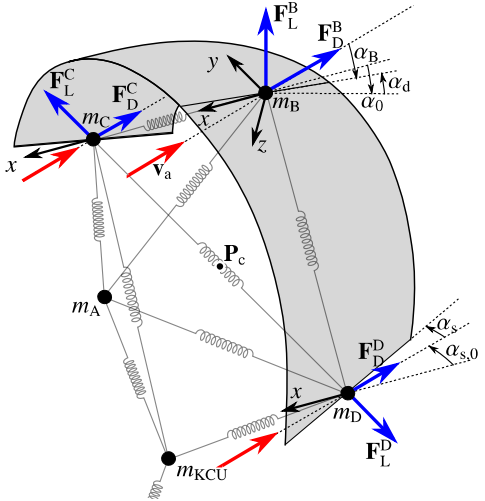


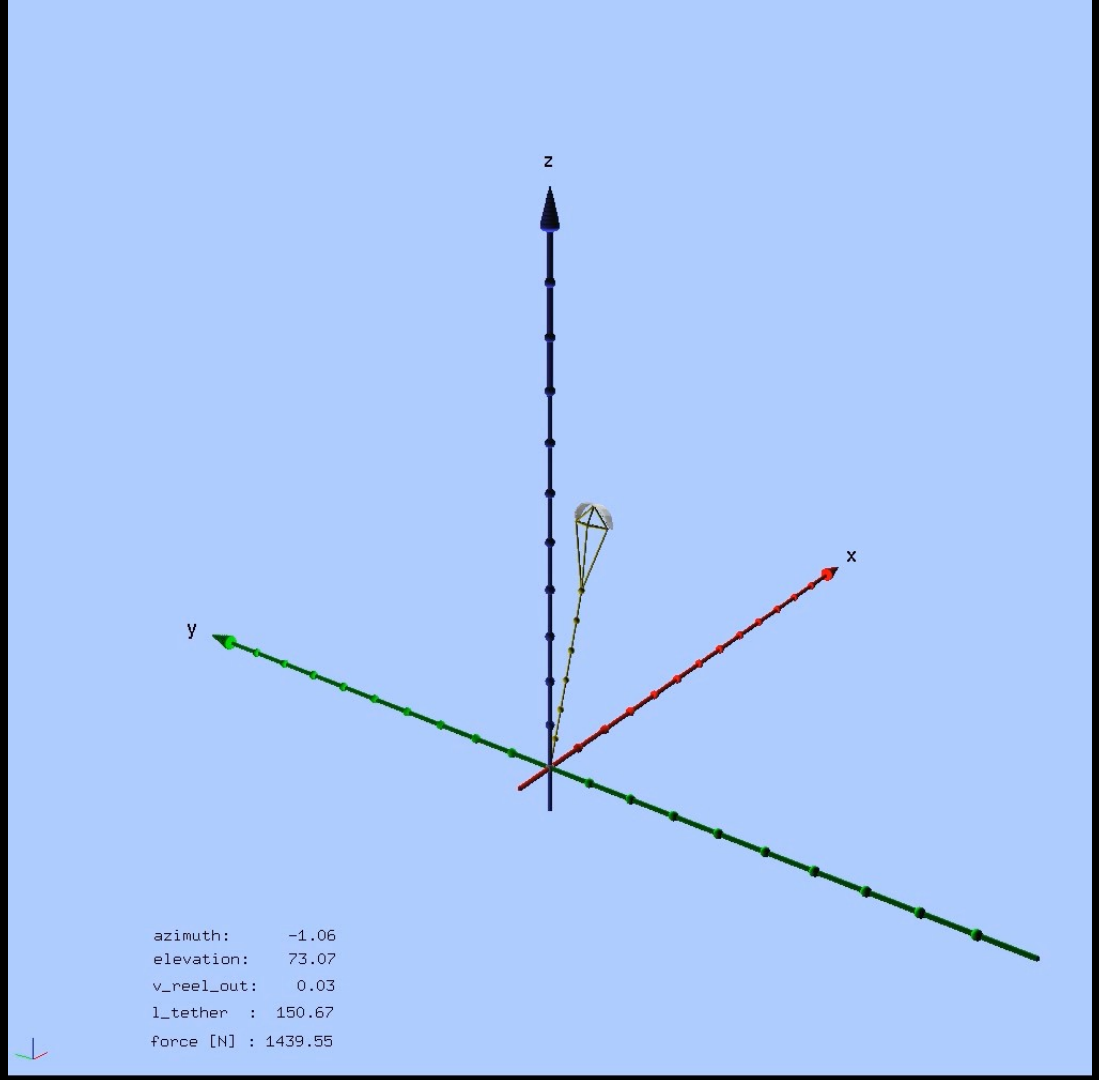


Dynamic system model

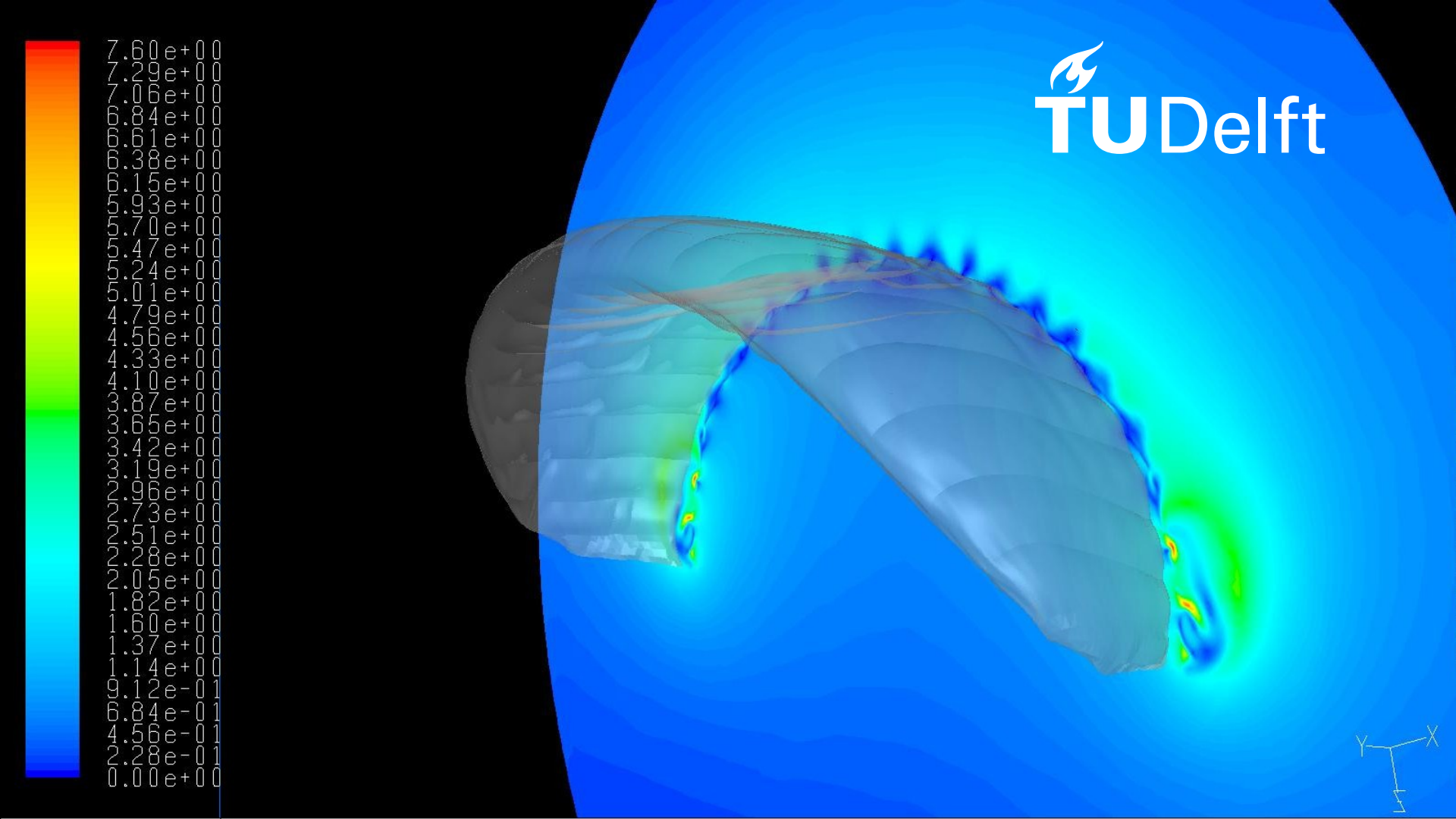
- Dynamic forces on system components
- Tether sag (gravity & aerodynamic drag)
- Coarse aero load distribution on wing
- Flight & winch controllers






z
x
y
azimuth: -1.06
elevation: 73.07
v_reel_out: 0.03
l_tether : 150.67
force [N] : 1439.55

Dynamic modelling challenges


7.60e+00
7.29e+00
7.06e+00
6.84e+00
6.61e+00
6.38e+00
6.15e+00
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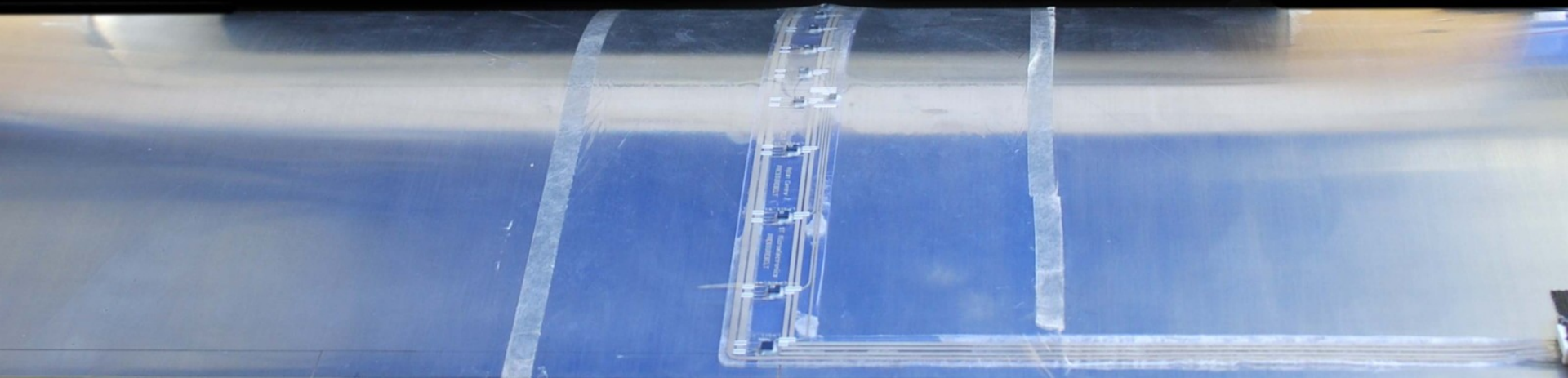
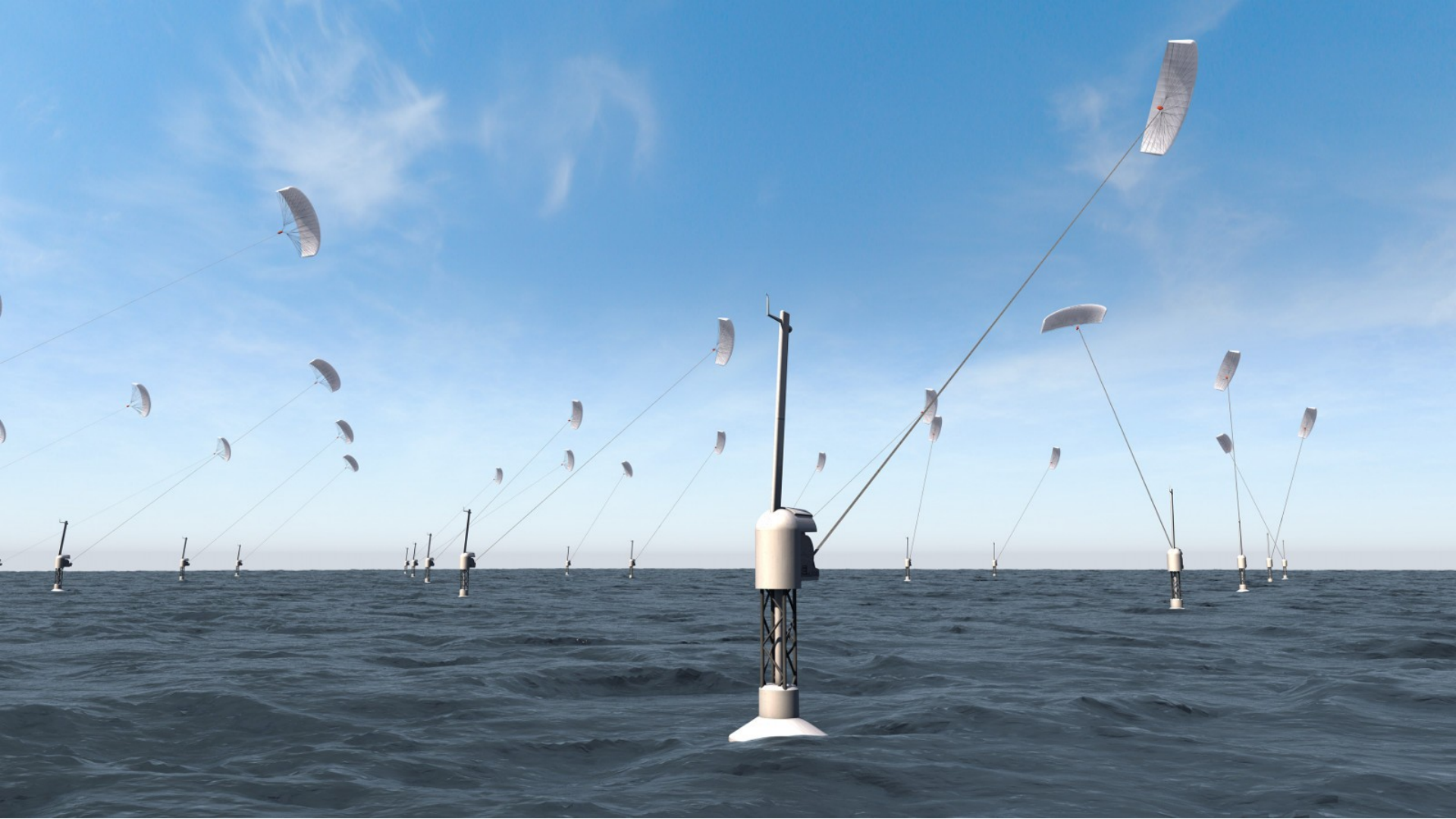
5.70e+00
5.47e+00
5.24e+00
5.01e+00
4.79e+00
4.56e+00
4.33e+00
4.10e+00
3.87e+00
3.65e+00
3.42e+00
3.19e+00
2.96e+00
2.73e+00
2.51e+00
2.28e+00
2.05e+00
1.82e+00
1.60e+00
1.37e+00
1.14e+00
9.12e-01
6.84e-01
4.56e-01
2.28e-01
0.00e+00
TUDelft
Y
X

Insitu Measurements

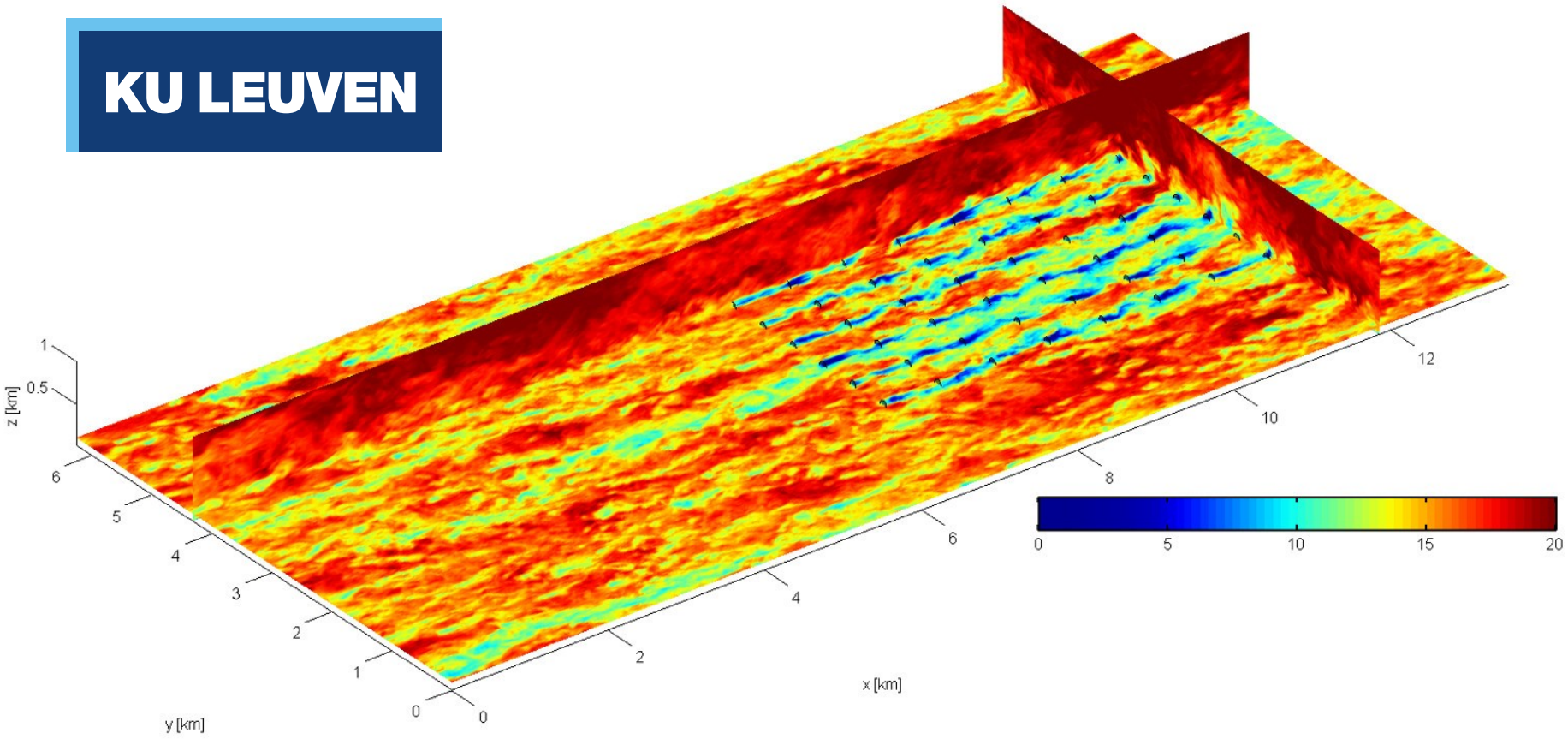
Flexible strip for measuring aerodynamic load distribution during flight operation




SkySails



KU LEUVEN



Conclusions

- Modelling and simulation is indispensable for efficient development of large-scale AWE systems
- Additional DoFs and complexity of operation represents extra challenges for physical model development
- Modelling and simulation approaches need to be tailored to application case and problem to be solved!