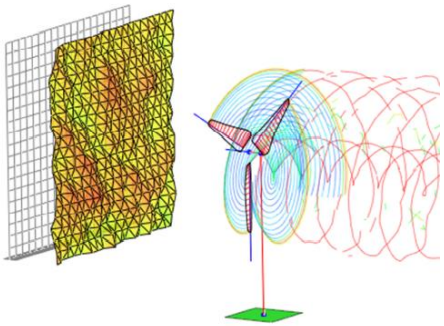
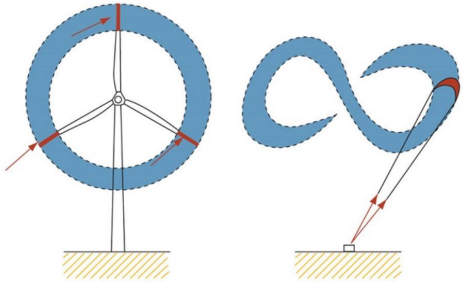
Von aktiven Rotorklappen und fliegenden Windkraftanlagen

- Aktuelle Windenergie-Forschungsaktivitäten der TU Berlin -





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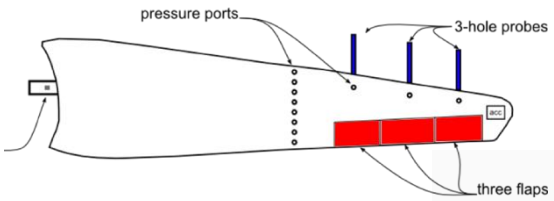
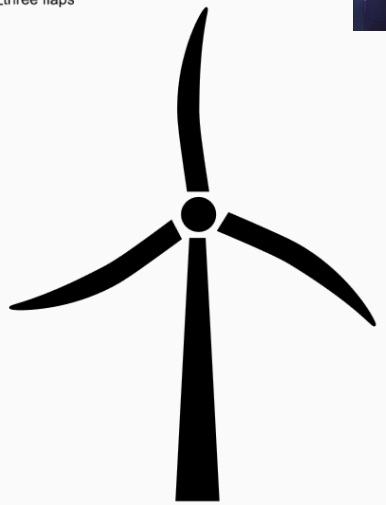
FG Experimentelle Strömungsmechanik
TU Berlin

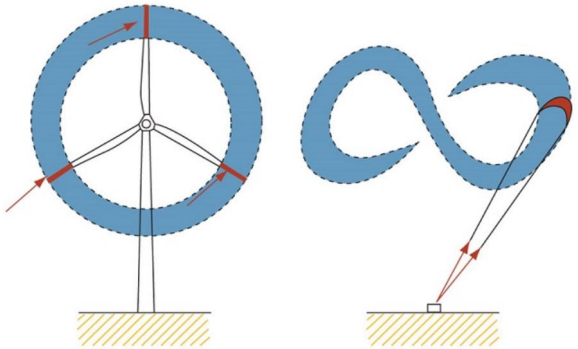
Windenergie Forschungsaktivitäten der TU Berlin
-Auswahl-

Part I: Rotorblattmodifikation





Part III: Flugwindkraftanlagen



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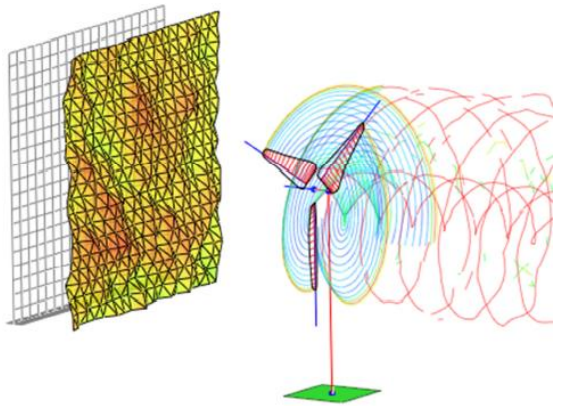

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C. O. Paschereit Institute of Fluid Mechanics and Acoustics
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Fachgebiet Experimentelle Strömungsmechanik TU Berlin

1927:

- Institut für Strömungslehre, TH Berlin
- Forschungs- und Prüfanstalt für Windkraftanlagen

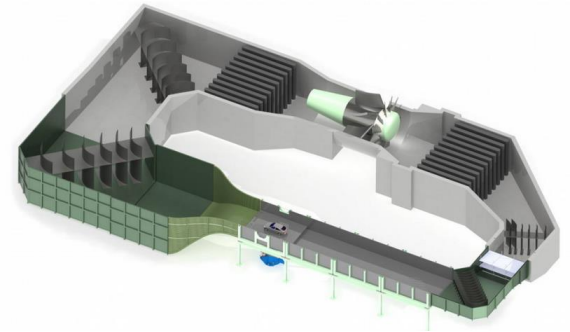
Aktuell: >40 Wissenschaftliche Mitarbeiter & Forscher

Forschungsschwerpunkte:
Experimentell & Simulativ

- Verbrennungsdynamik
- Turbulente Strömung
- Aerodynamik
- Windenergie

Simulation:
2D/3D CFD
Lifting-Line-Theory
QBlade

Experimentelle Einrichtungen
Fünf Windkanäle
Europas zweitgrößter Schleppkanal



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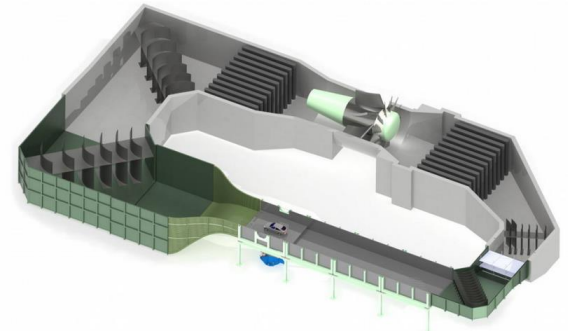

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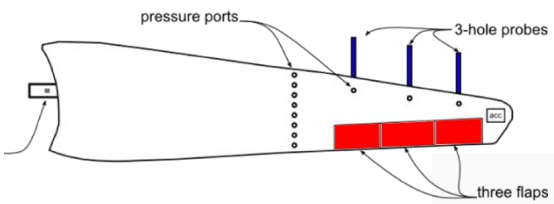
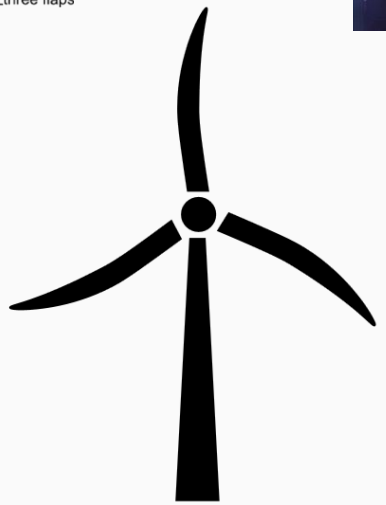
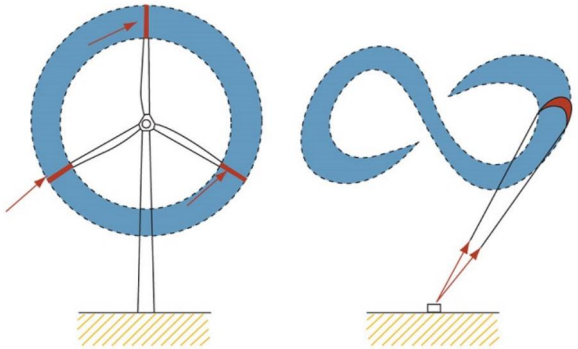
Windenergie Forschungsaktivitäten der TU Berlin

Part I: Rotorblattmodifikation

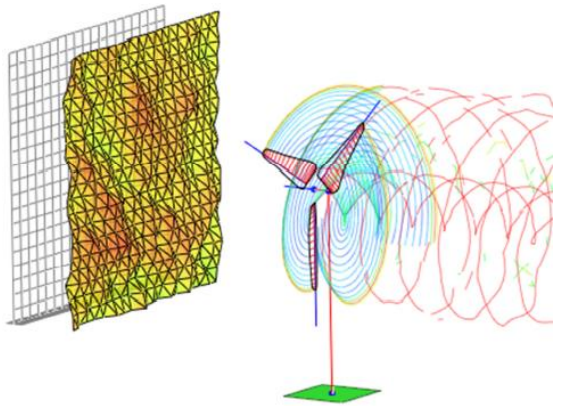




Part III: Flugwindkraftanlagen



Part II: WKA Software Entwicklung



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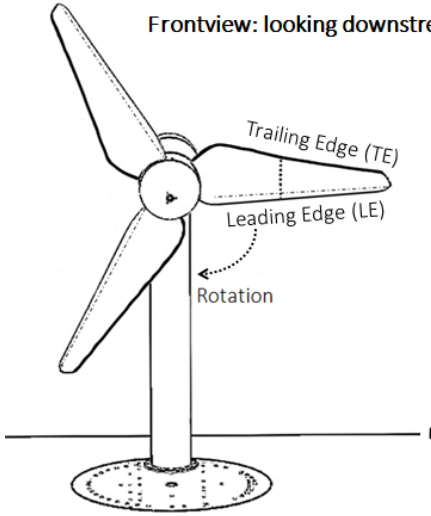
Forschungsaktivitäten Part I: Rotorblattmodifikation

Berlin Energy Research Turbine (BERT)

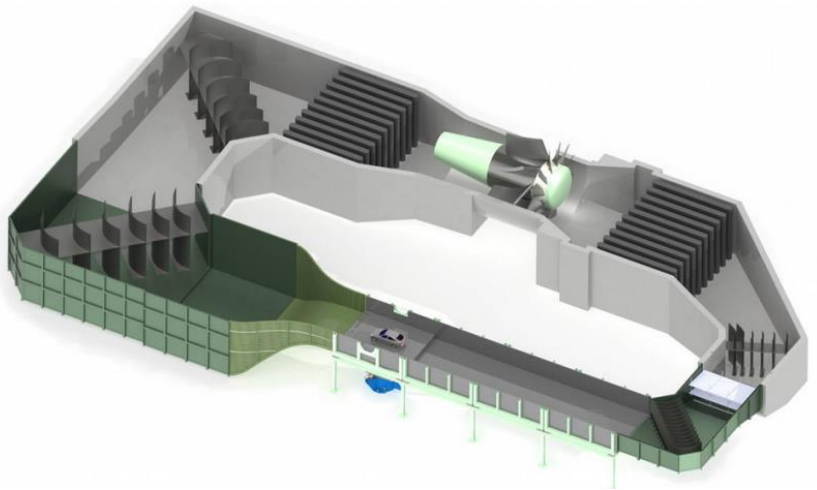
- Aktive und passive Strömungskontrolle
- Gourney Flaps, Vortex Generators
- Kraft- und Druckmessung
- Strömungsvisualisierung PIV

- **Ziel**: Lastenreduktion und Effizienzsteigerung



BeRT-Specifications	
Rotor radius	1.5m
Wind-tunnel	4.2m x 4.2m
Blockage ratio	40%
Hub-height	2.1m
Single Airfoil	Clark-Y
Data sampling rate	10 kHz

Raw-data aquisition with NI cRIO/cDAQ platform and LabVIEW tool



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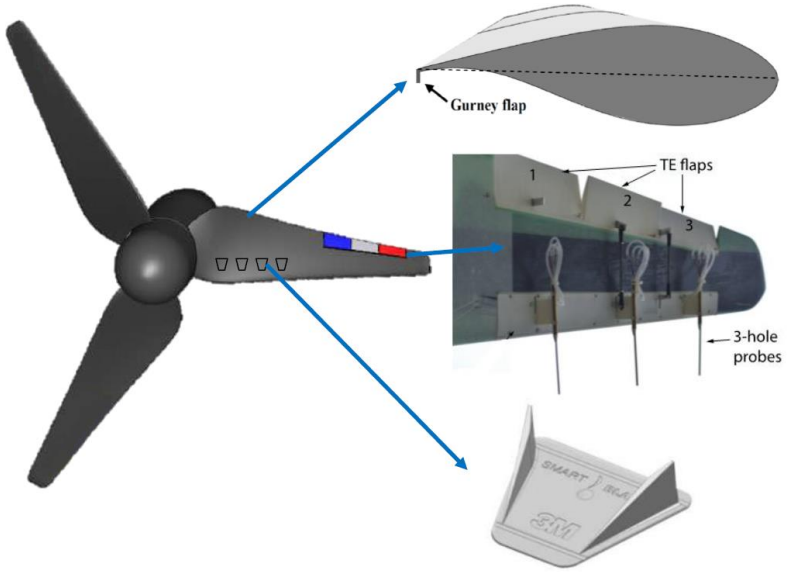
Forschungsaktivitäten Part I: Rotorblattmodifikation

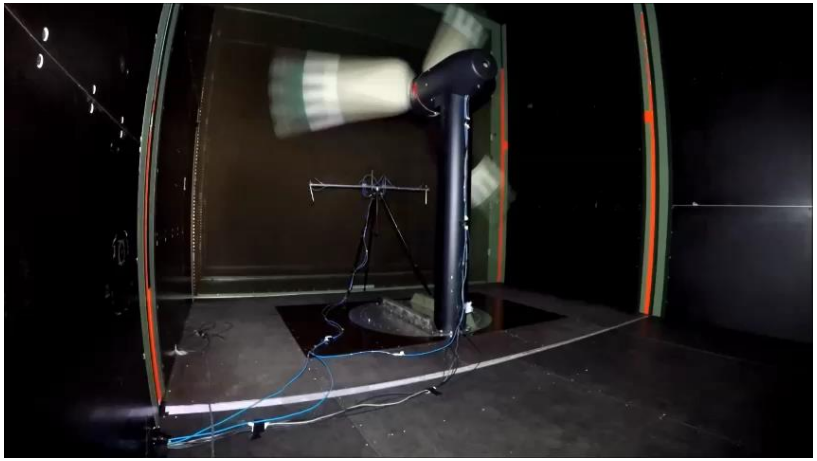
Aktive Rotorblattklappen

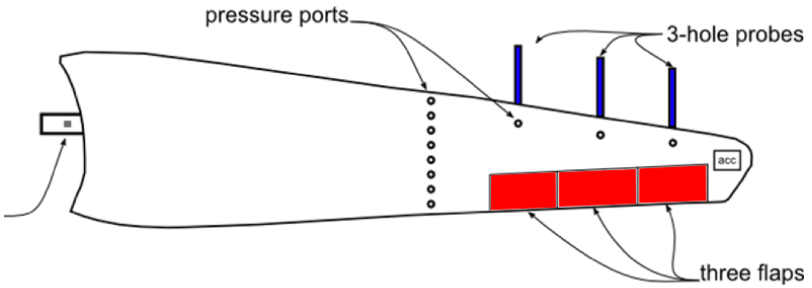
Messung von AoA (Angle of Attack)
Aktivierung der Klappen zur Lastreduktion

Anwendungsfall:
Böen/Schräganströmung/Turmvorstau

Ziel: Materialeinsparung durch Lastreduktion







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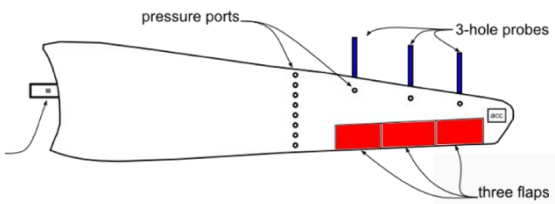
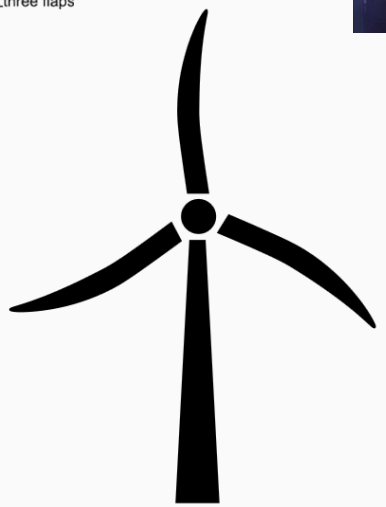
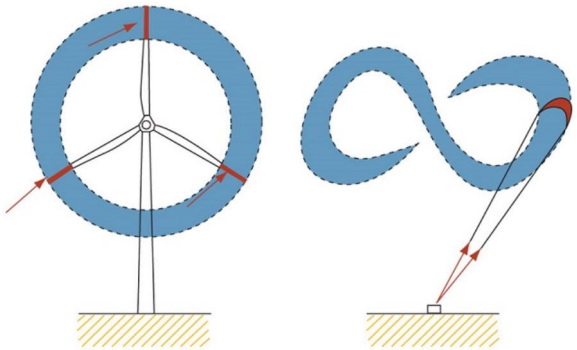
Windenergie Forschungsaktivitäten der TU Berlin

Part I: Rotorblattmodifikation

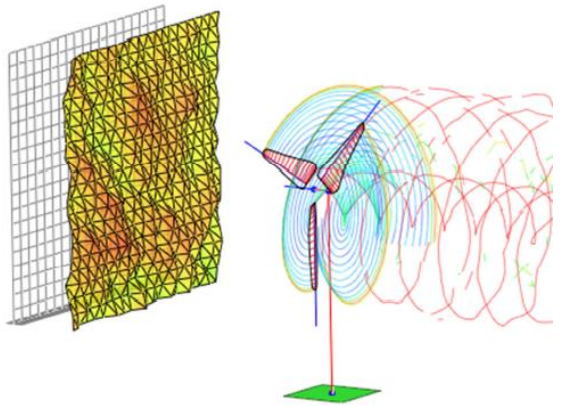




Part III: Flugwindkraftanlagen



Part II: WKA Software Entwicklung



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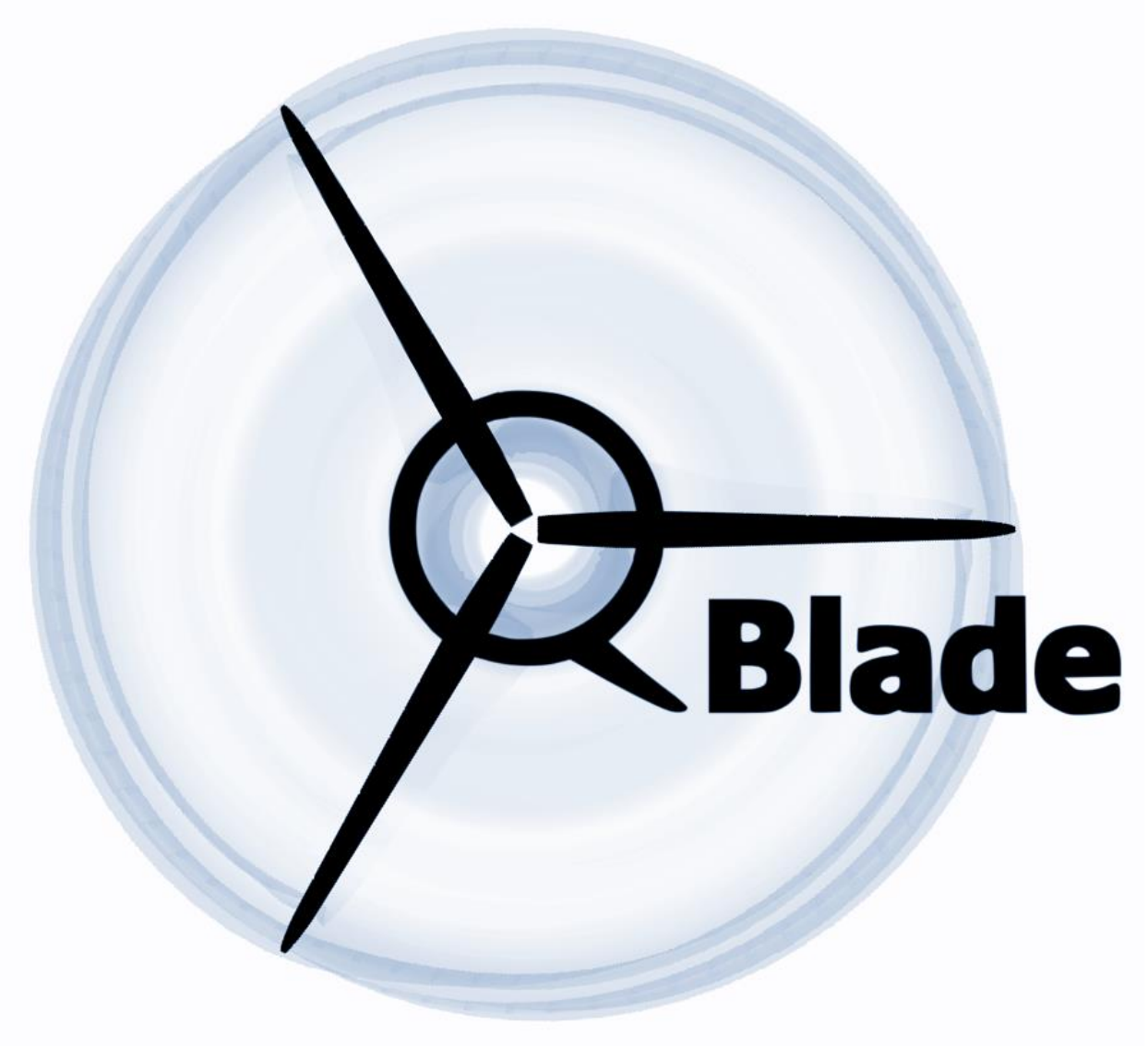
Forschungsaktivitäten Part II: WKA Software-Entwicklung



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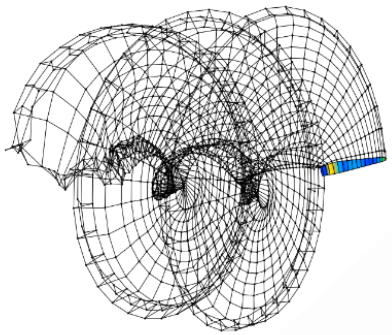
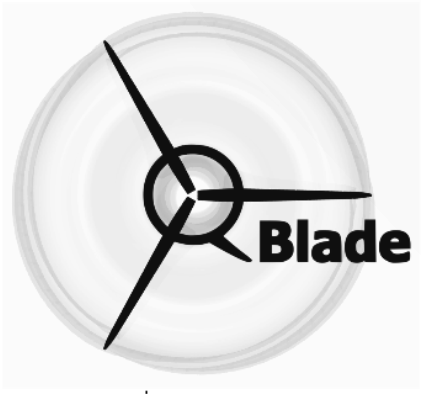
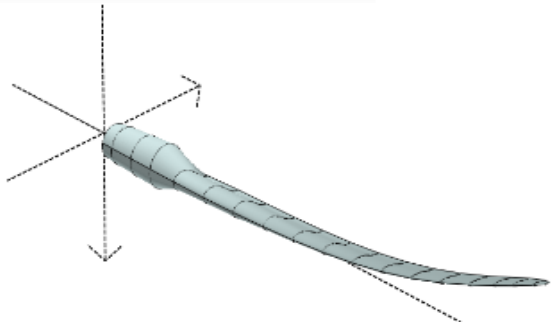
Forschungsaktivitäten Part II: WKA Software-Entwicklung

In-House Entwicklung von Windkraftanlagen Simulationstools

- Intuitive Design und Simulationsumgebung für Horizontal- und Vertikal- windkraftanlagen
- Stationär und instationäre Simulation der Aerodynamik mittels BEM und High-Order-Aerodynamik Modell Lifting-Line-Theory
- Rotorblattauslenkung und Eigenfrequenzanalyse
- Intuitive Kopplung mit Aeroelastischem Simulationstool FAST (NREL)
- Mehr als 30.000 weltweite Downloads, Kernversion OpenSource, modular erweiterbar (Floating Platform, Airborne, Structural Solver etc.)







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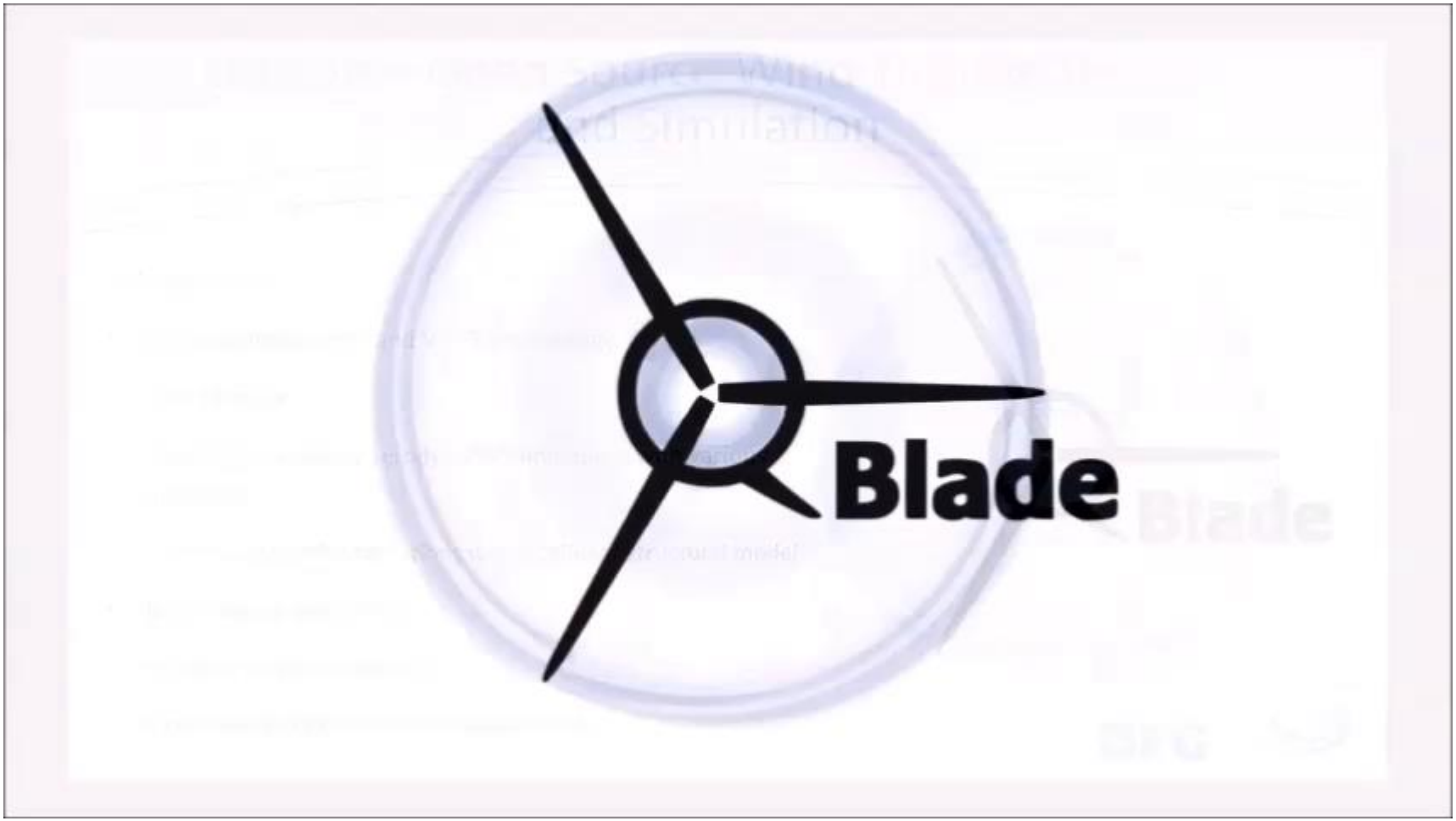
Forschungsaktivitäten Part II: WKA Software-Entwicklung



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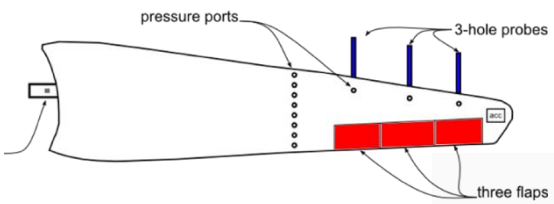
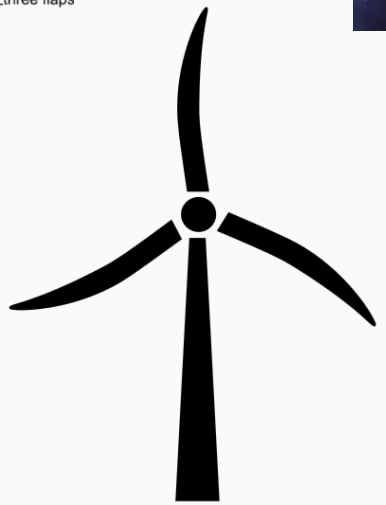
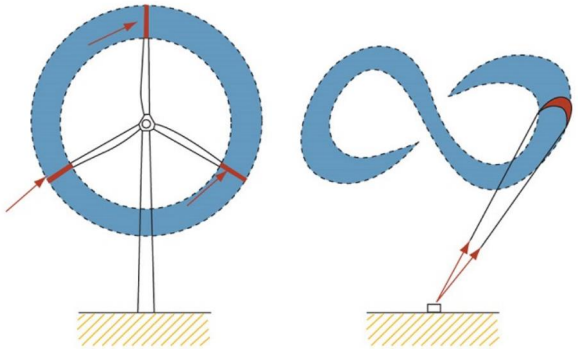
Windenergie Forschungsaktivitäten der TU Berlin

Part I: Rotorblattmodifikation

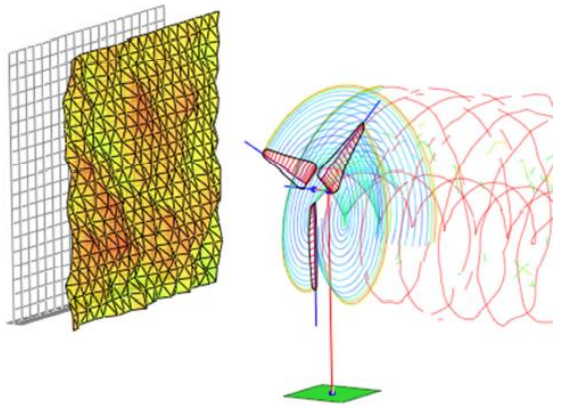




Part III: Flugwindkraftanlagen



Part II: Software Entwicklung



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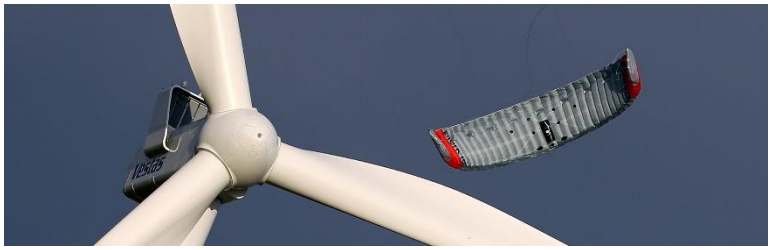
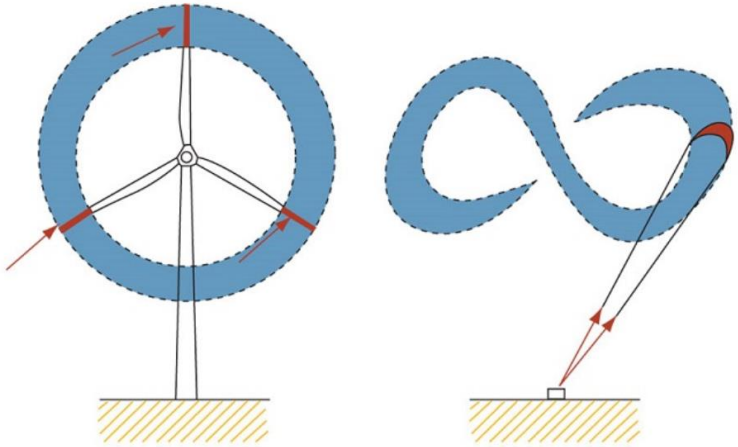
Forschungsaktivitäten Part III: Flugwindkraftanlagen

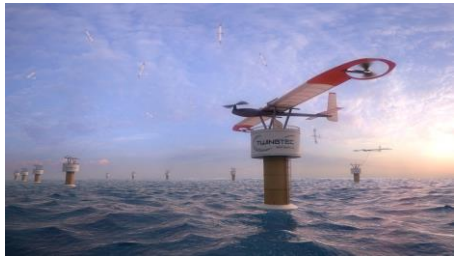


Flugwindkraftanlagen Airborne Wind Energy Systems

Motivation:

1. Signifikante Materialeinsparung
2. Erhöhte & Kontinuierliche Energieausbeute





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Forschungsaktivitäten Part III: Flugwindkraftanlagen
Materialeinsparung

Trend in konventioneller Windenergie

- Höhere Nabenhöhen
- Größere Rotordurchmesser

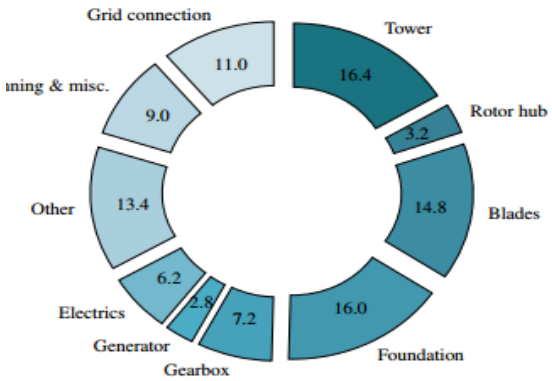
Problem:

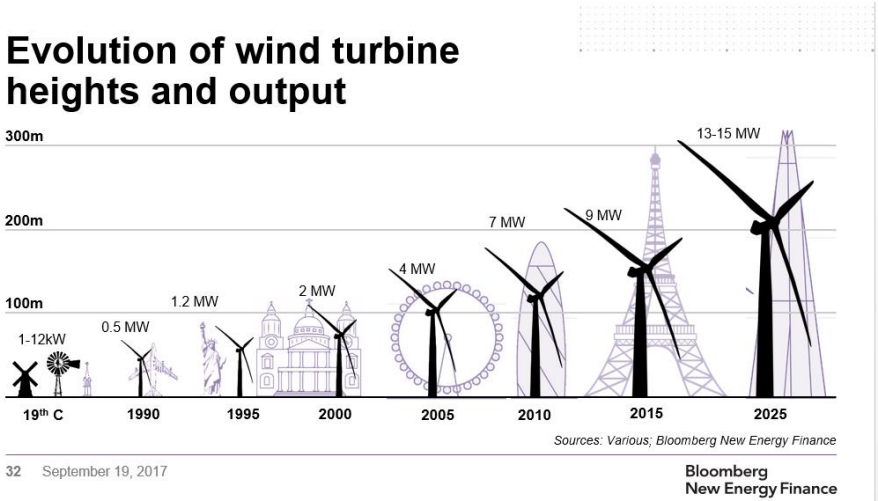
- Verdopplung der Rotorfläche→ Verachtfachung der Masse
  $m \sim V \sim R^3$
- Hohe Nabenhöhen → Hohe Turmfussbiegemomente → Material

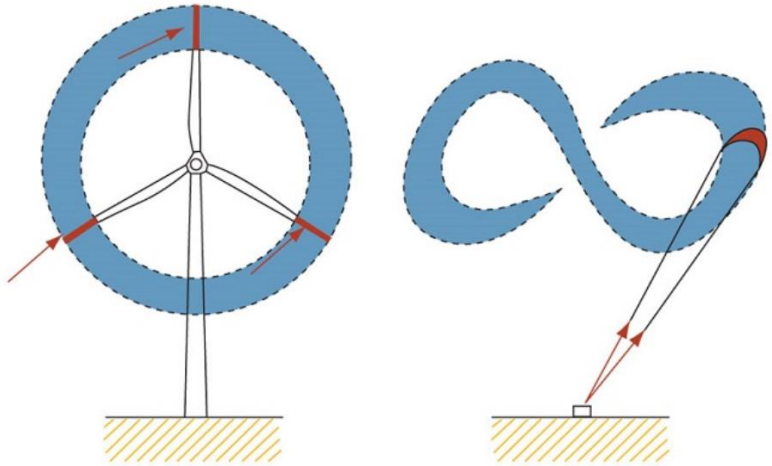
Idee der Flugwindkraftanlagen:

- Nabenhöhen bis 1000m
- „Wir ersetzen von Stahl durch Seil und Software“

Udo Zillmann and Philip Bechtle







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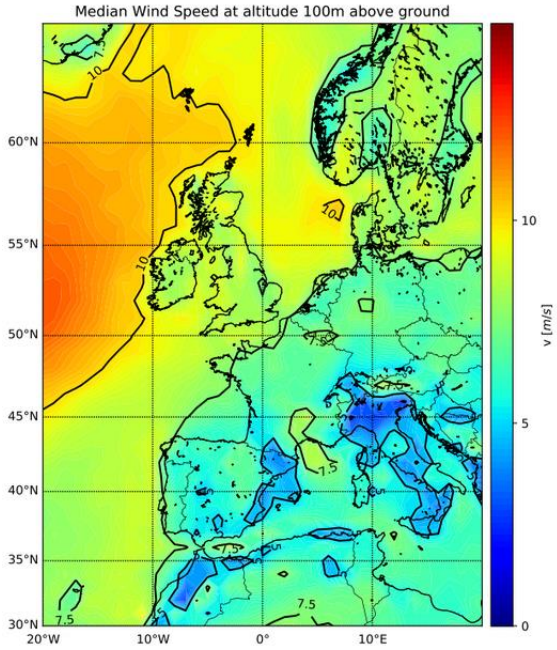
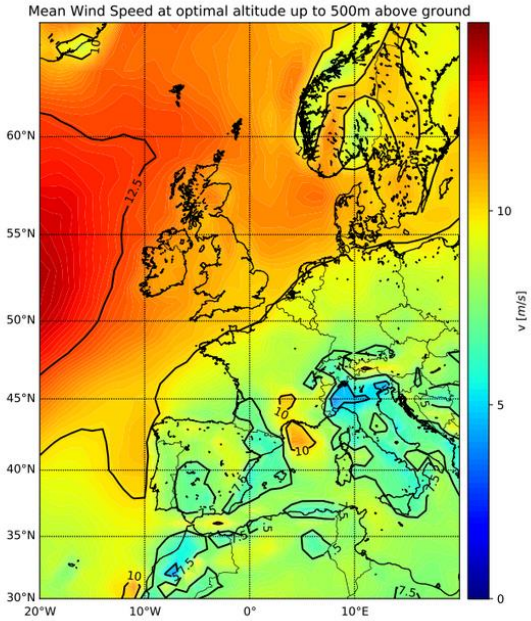
Forschungsaktivitäten Part III: Flugwindkraftanlagen
Motivation Energieausbeute

Windgeschwindigkeiten & Häufigkeiten in 500m Höhe





$$Power = \frac{1}{2} \cdot \rho_{Luft} \cdot A_{rotor} \cdot c_P \cdot v^3$$

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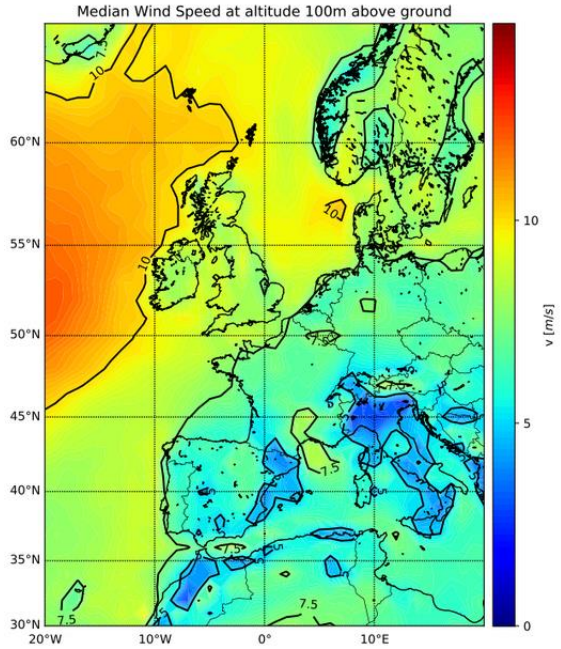
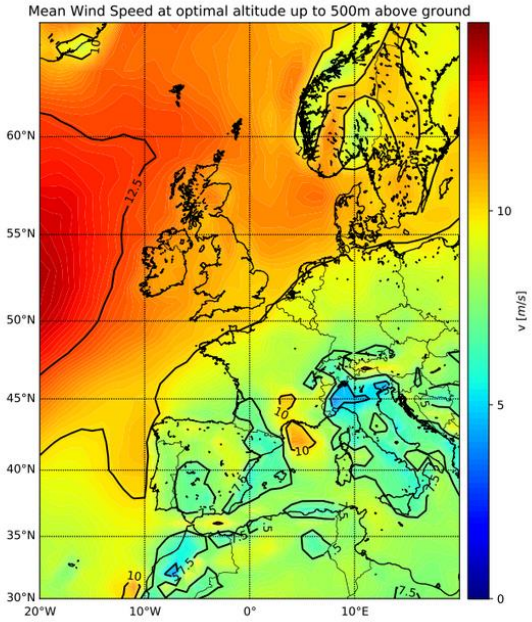
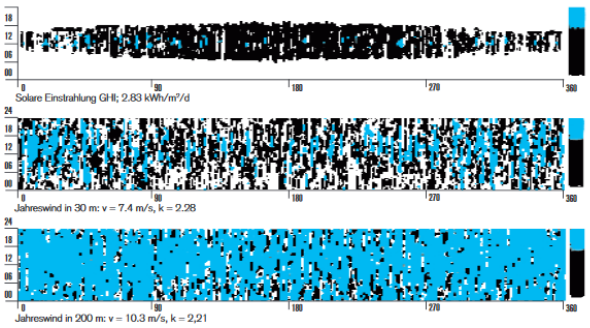
Windgeschwindigkeiten & Häufigkeiten in 500m Höhe







12% PV

35% WKA

75% EK

$$Power = \frac{1}{2} \cdot \rho_{Luft} \cdot A_{rotor} \cdot c_P \cdot v^3$$

$$Energy = Power \cdot Operational\ Time$$

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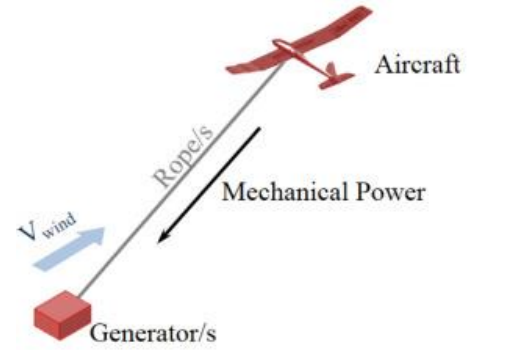
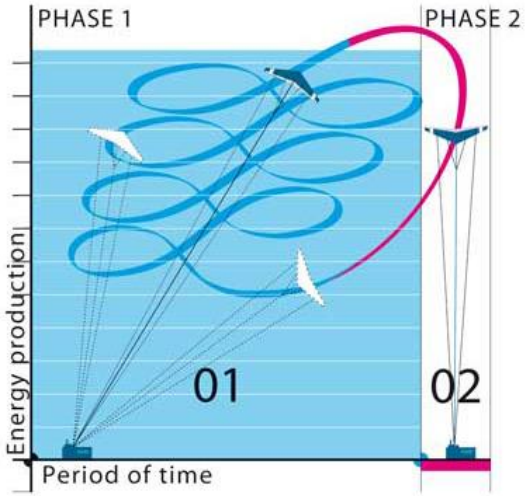
Forschungsaktivitäten III: Flugwindkraftanlagen

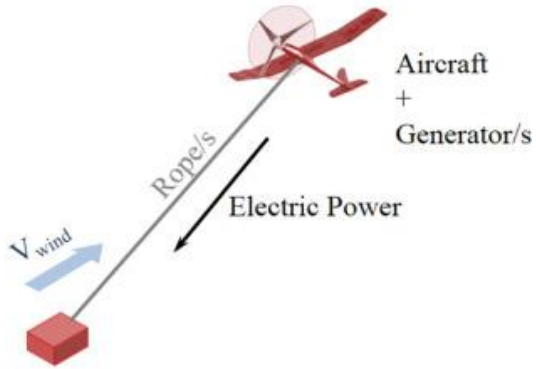
Die 2 Hauptkonzepte der Flugwindkraft

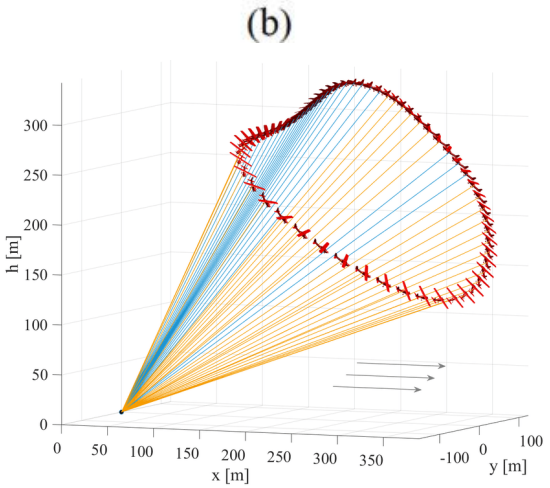
Stromproduktion an Bodenstation





Stromproduktion am Fluggerät





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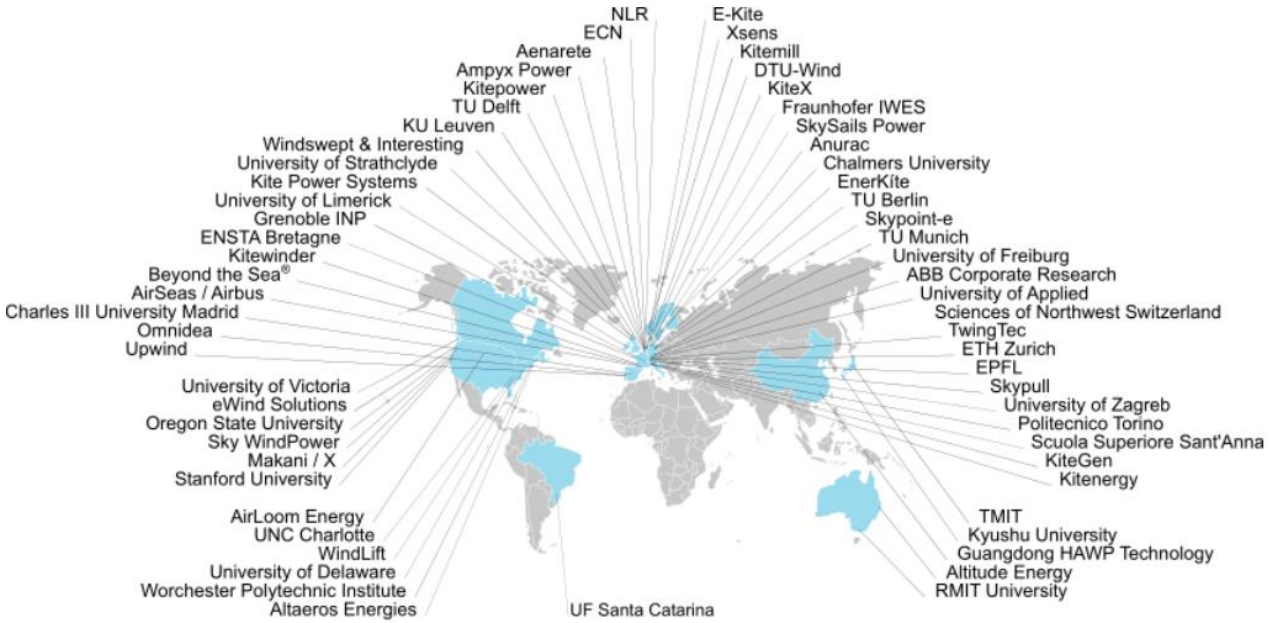
Forschungs – und Industrieaktivitäten



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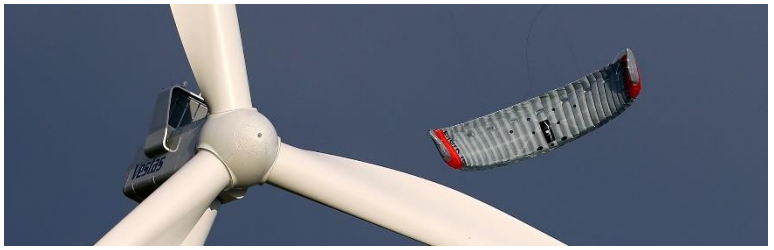
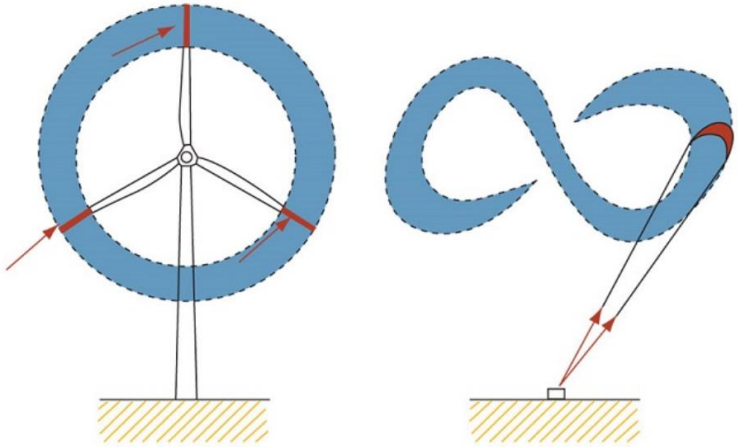
Forschungsaktivitäten Part III: Flugwindkraftanlagen

Airborne Wind Energy Systems



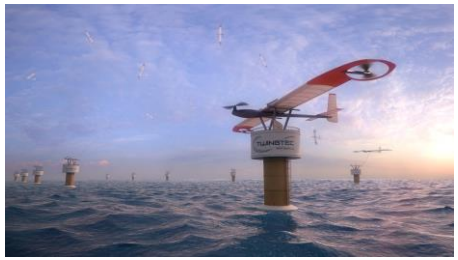
Motivation:

1. Signifikante Materialeinsparung
2. Erhöhte & Kontinuierliche Energieausbeute



Ziel:

1. Multi-MW Anlagen in 3-6 Jahren
2. Offshore Repowering Markt
3. LCOE 0.05 – 0.07 €/kWh
4. AEP im Gigawatt Bereich



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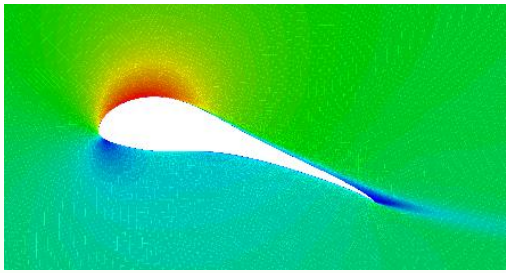
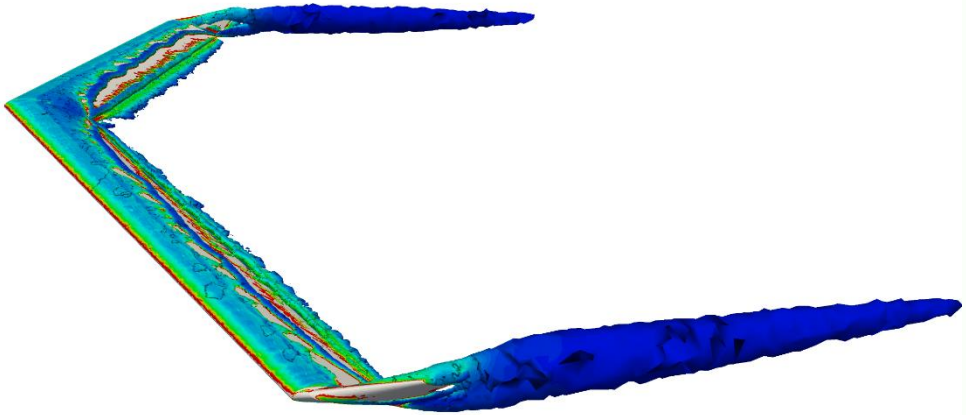
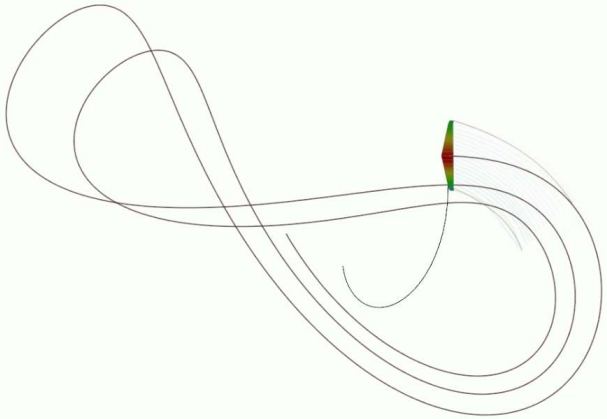
Forschungsaktivitäten III: Flugwindkraftanlagen

Forschungsaktivitäten der TU Forschungsgruppe “Airborne Wind Energy Systems”

- Numerische Analyse der Flugdynamik und Flugperformance (Lifting-Line-Theory)
- In-House Software Entwicklung zur Simulation von Flugwindkraftanlagen
- Entwicklung leistungsoptimierter Tragflügelprofile für Flugwindkraftanlagen
- Experimentelle Untersuchungen in Wind- und Wasserkanal







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Die 250 m lange Schlepprinne der TU Berlin

Vorteile:

- Hohe Reynoldszahlen
- Langsame Strömungsgeschwindigkeiten → Hohe Messauflösung

Messmethoden:

- Optisch (PIV)
- Kraft (Druck,DMS)

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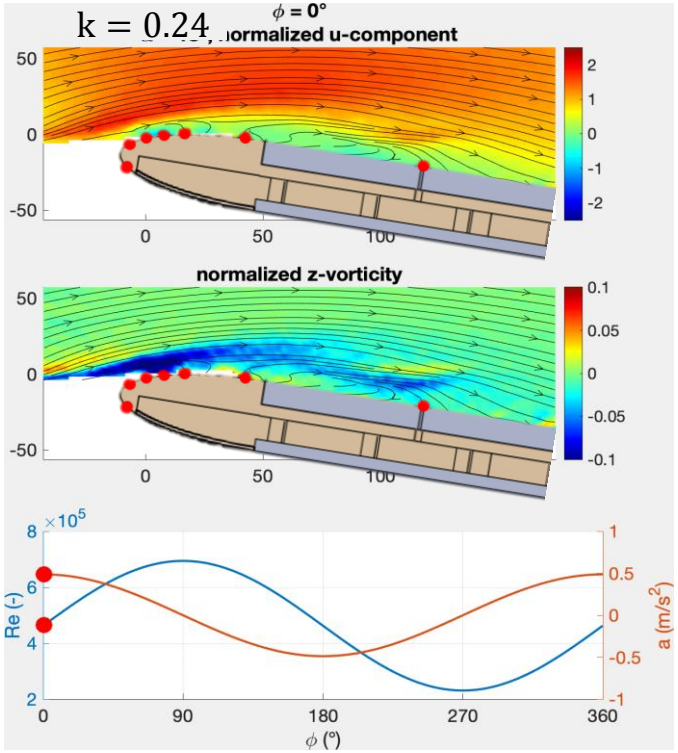
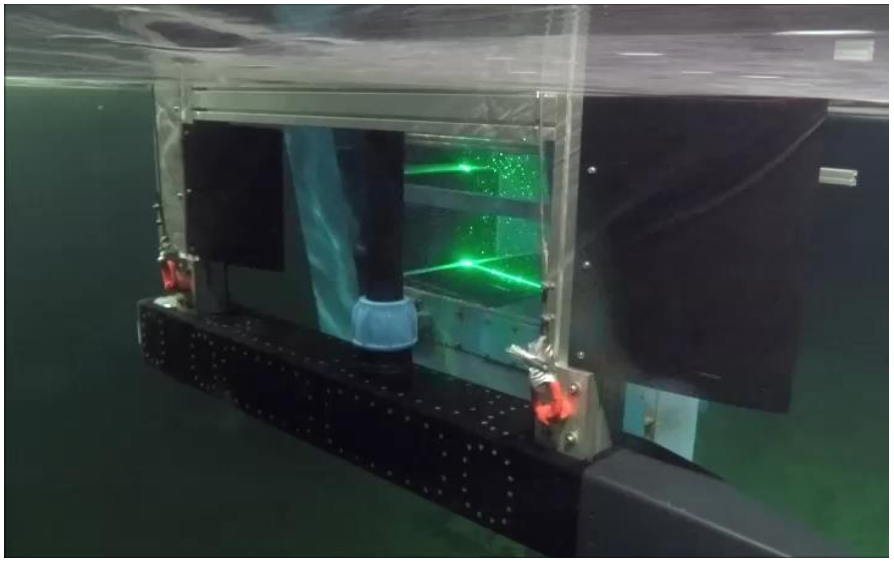
Forschungsaktivitäten III: Flugwindkraftanlagen

Forschungsaktivitäten im 250m Schleppkanal

- Zero-Turbulence Experimente
- Untersuchung dynamischer Strömungsphänomene (Kraftmessung, Strömungsvisualisierung, Druck)

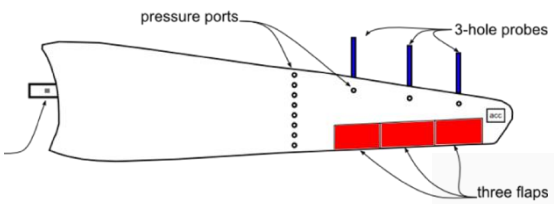


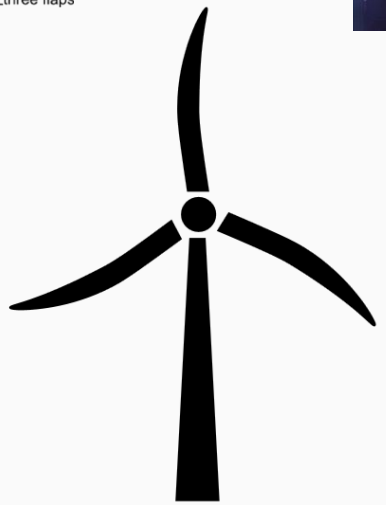


$\alpha = 18°, \overline{Re} = 0.44 \cdot 10^6$

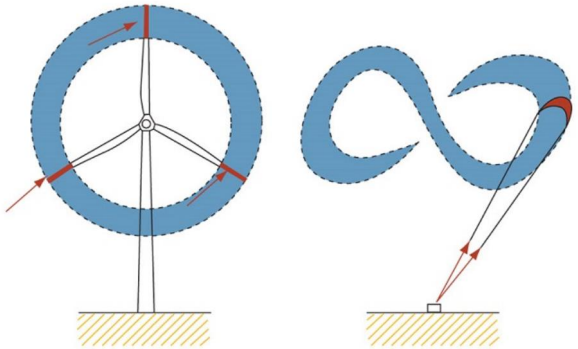
Windenergie Forschungsaktivitäten der TU Berlin

Part I: Rotorblattmodifikation

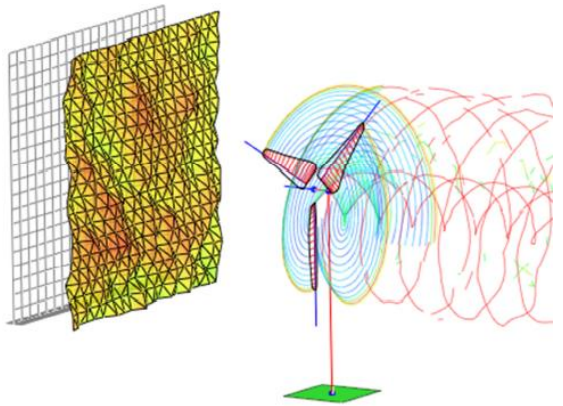




Part III: Flugwindkraftanlagen



Part II: WKA Software Entwicklung



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Vielen Dank für die Aufmerksamkeit

Fragen , Anregungen & Projektideen

- Sprechen Sie uns gerne an -

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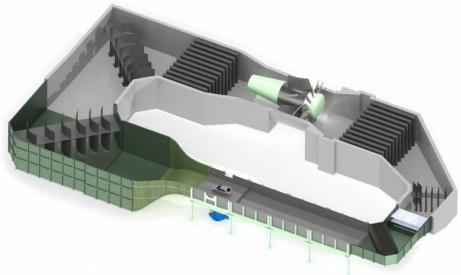
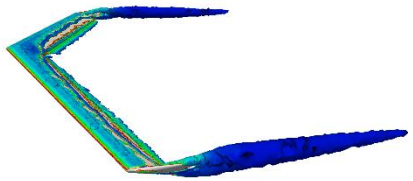
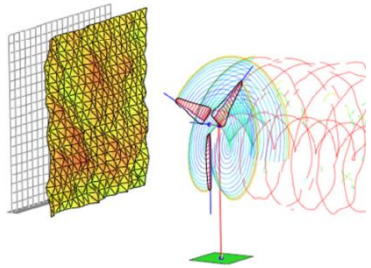
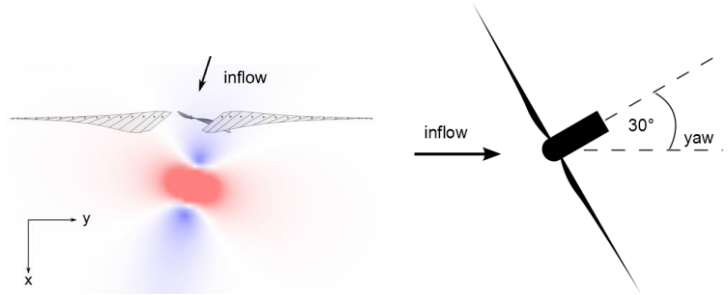


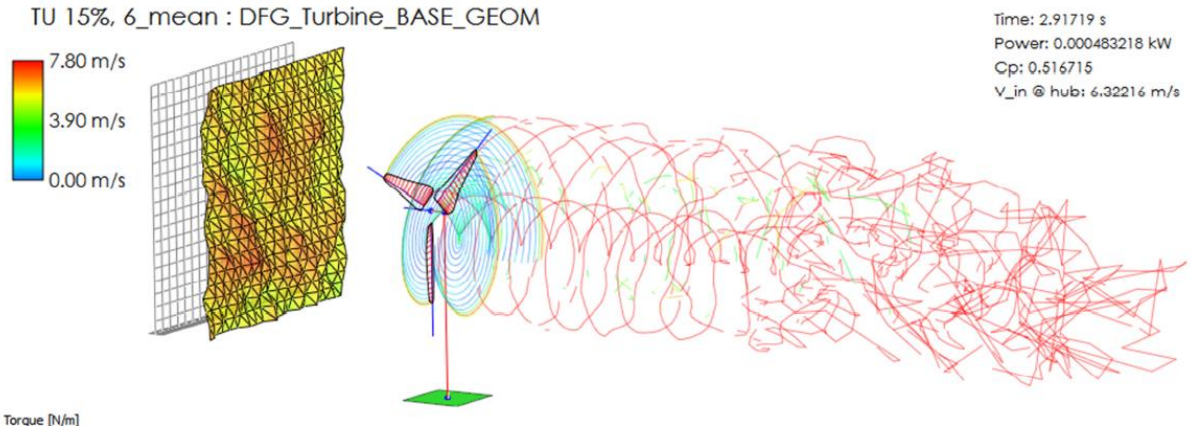


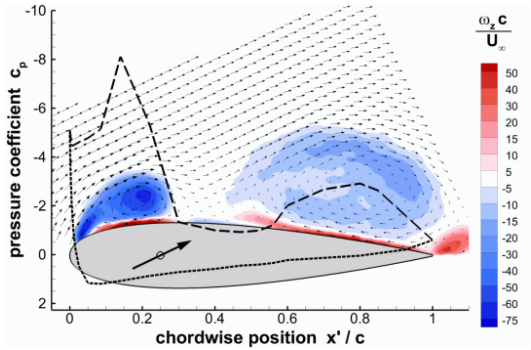


Appendix- QBlade Functionality

- Time accurate simulations with turbulent wind fields
- Arbitrary motion of rotor (pitch, yaw, blade deflections)
- Tower influence → potential flow around cylinder
- Vortex modeling with viscosity and time decay
- Dynamic stall model (to be implemented)







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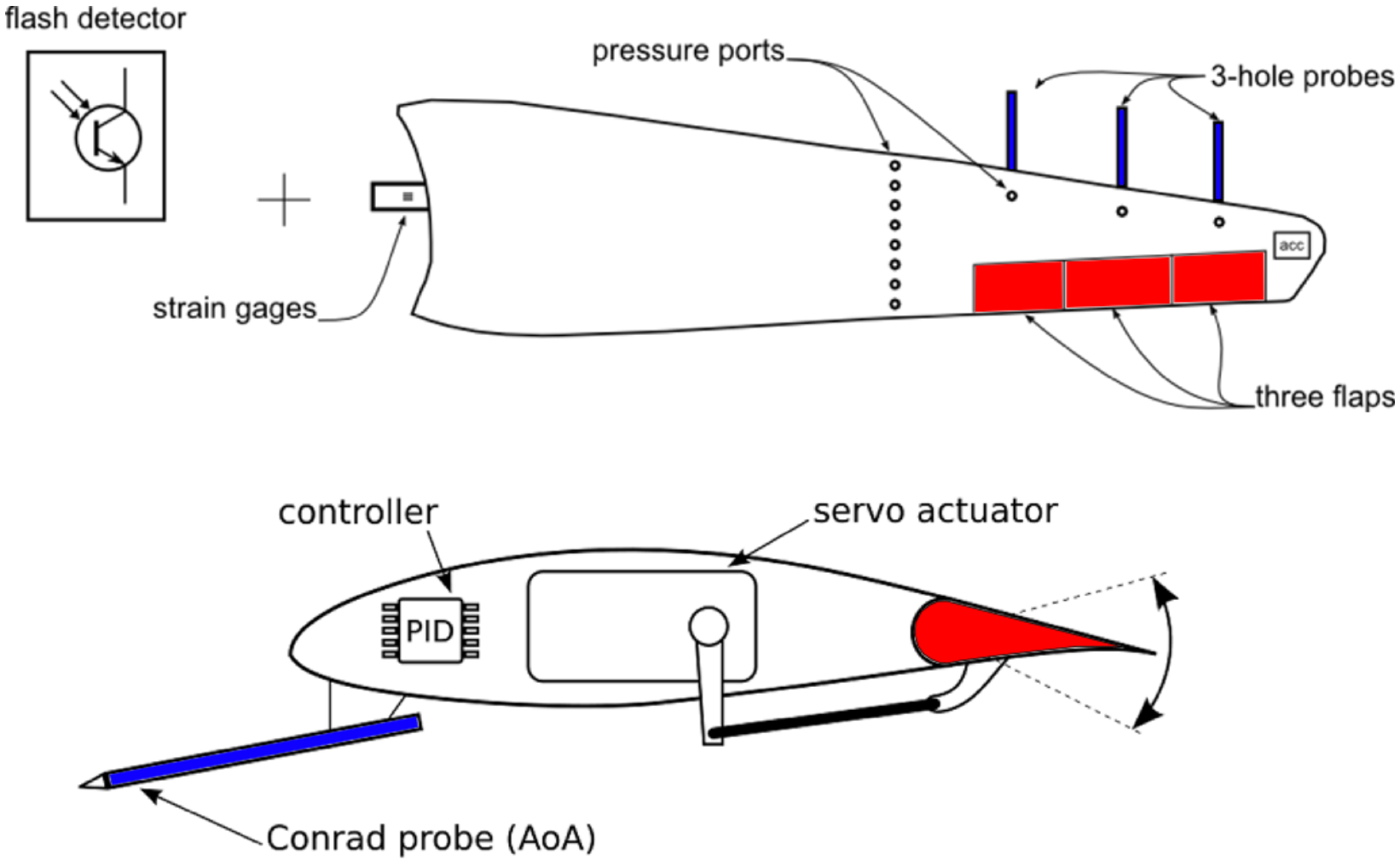
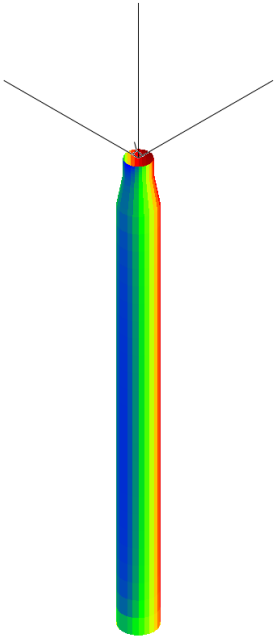
Appendix- Active Rotor Blades

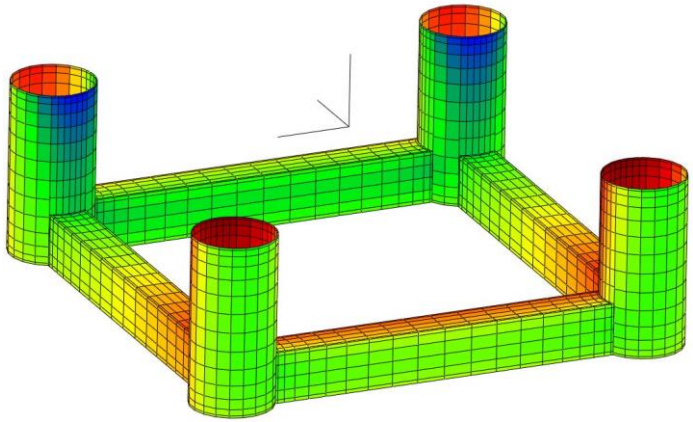


Appendix- Hydrodynamic Model

BEMUse: Hydrodynamic Problems



- Hydrodynamics module
  - Calculation of hydrodynamic forces:
    - Waves (diffraction problem),
    - Floater motion (radiation problem)
  - Hydrostatic loading
  - Hydrodynamic mass and damping matrices



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