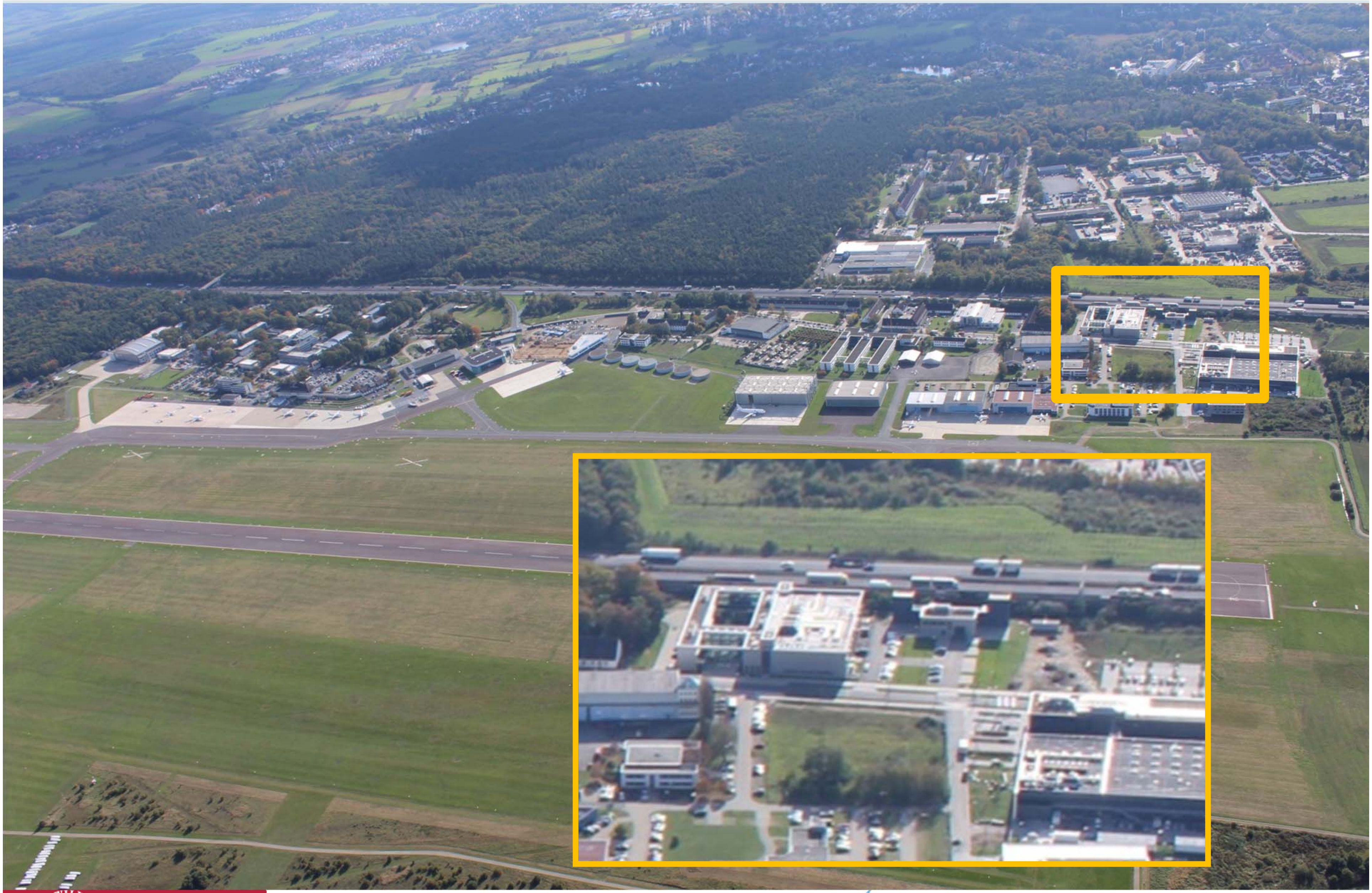
Technische Universität Braunschweig

IFAS Institut für Flugantriebe und Strömungsmaschinen

A view into the turbomachinery research activities at IFAS

CA^{3}ViAR Dissemination Event

September 2022

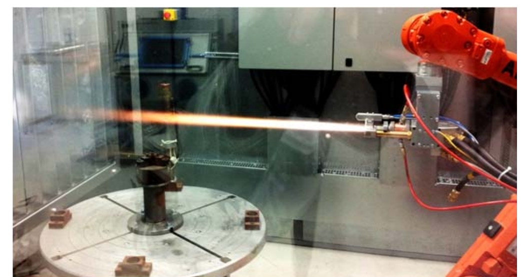


About the NFL

- Founded 2009 by leading scientists of aeronautics and aerospace in Braunschweig
- Interdisciplinary research centre of Technische Universität Braunschweig
- In cooperation with the German Aerospace Research Centre DLR
- participating institutions:
  - TU Braunschweig, DLR (Braunschweig and Göttingen), LU Hannover, PTB, Fraunhofer
  - 21 institutes with about 1000 scientific staff








Identity and Mission

Identity

- NFL is the scientific centre of all aerospace research institutes of TU Braunschweig, DLR and LU Hannover
- NFL is the scientific network at the Research Airport Braunschweig
- NFL promotes coordinated programmes stimulating excellent research
- broad TRL range: from fundamental research to application-oriented development and testing

Mission

- Initiating, planning and coordinating of fundamental, interdisciplinary research
- Development of long-term R&D strategy
- Coordination of large-scale investments
- Representation of interests of all members towards society, industry and politics

IFAS - Organisation

Leitung

Prof. Dr.-Ing. J. Friedrichs

Propulsoren

Prof. Dr.-Ing. J. Friedrichs

Skalenauflösende Aerodynamik in Turbomaschinen

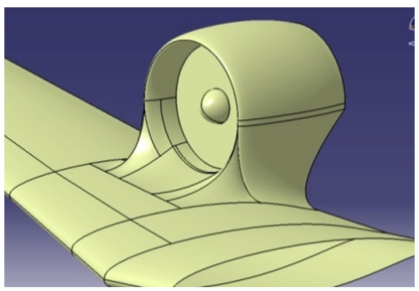
Dr.-Ing. C. Bode

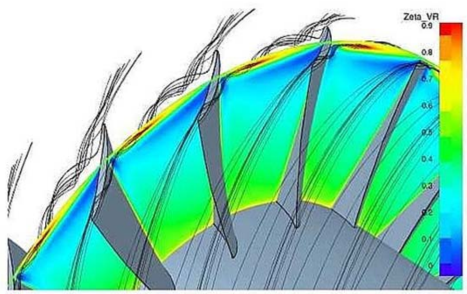
Systemdynamik & Modellierung

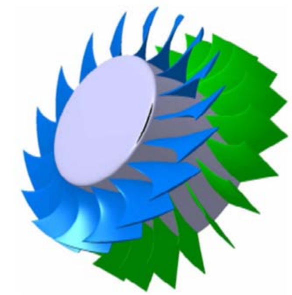
Jan Göing, M.Sc.

Hydraulische Maschinen - Komponenten und Dichtungen

Dr.-Ing. H Schwarz



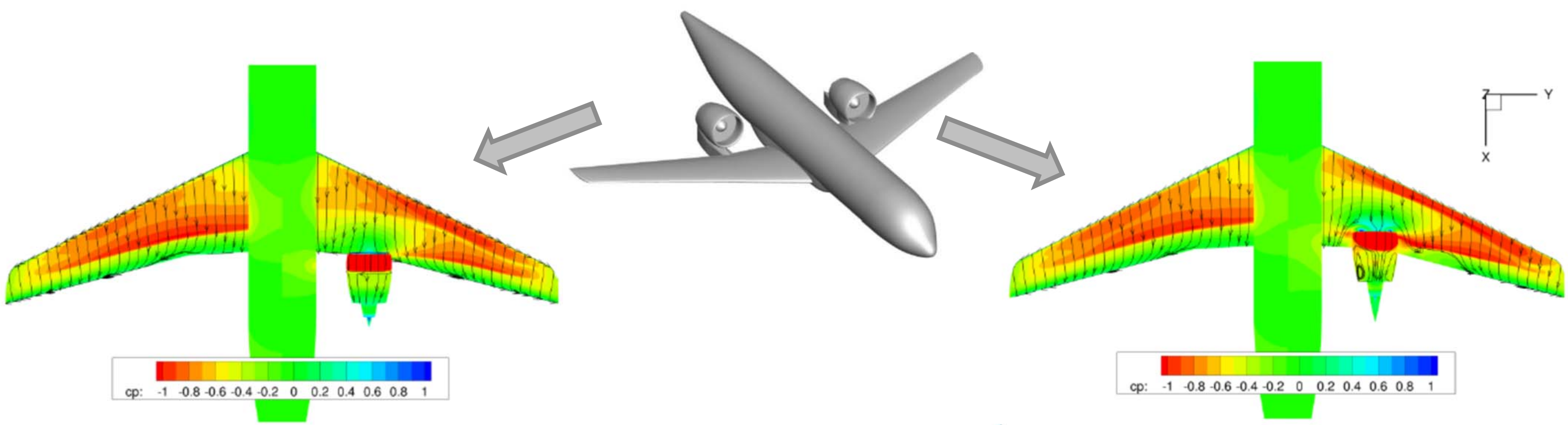




- Scientists: 27
- Technicians: 2
- Mechanical Shop: 8 (Joint Shop between Aerospace Institutes @ TU Braunschweig)
  CNC Milling (5-axis), CFRP
- Lab Area: 2000 m² (together with Institute of Fluid Mechanics)

Engine Integration (DFG - CRC880)

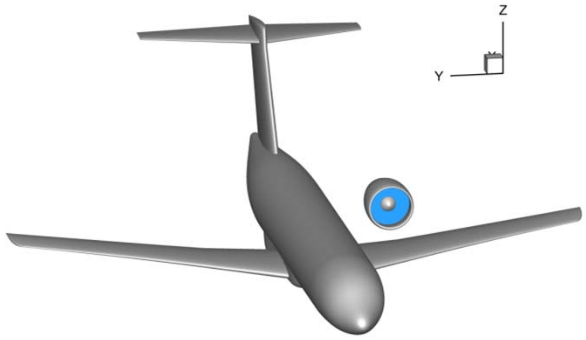
- Project A3 focussing on engine integration in cooperation with DLR-AS
- Aerodynamic assessment for pylon-engine coupling (DLR) and embedded engines (IFAS)
- Thermo-aerodynamic engine design (BPR = 17), separated nozzle arrangement
- Nacelle design (IFAS); Pylon-design and integration sensitivity (DLR); BLI and local 3D design of nacelle-wing area (IFAS)

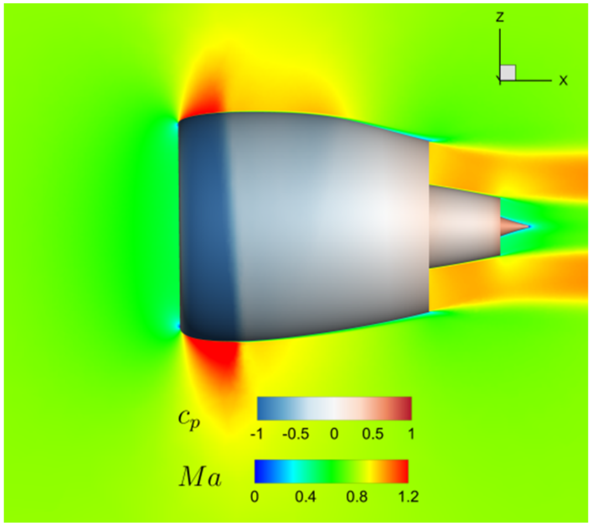


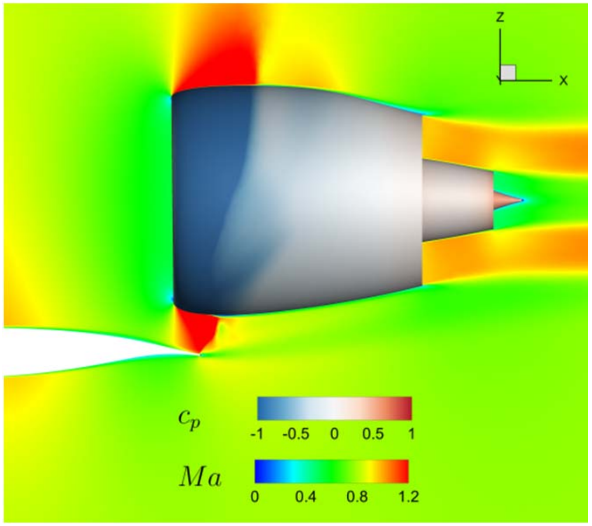
Engine Integration (DFG - CRC880)

Over-the-wing installation of the UHBR nacelle

- Interaction between nacelle inflow and flow around the wing
- Flow around lower nacelle lip leads to positive installation effect (pos. thrust)
- But: Double-shock on upper wing side produces additional losses (pylon and embedded)



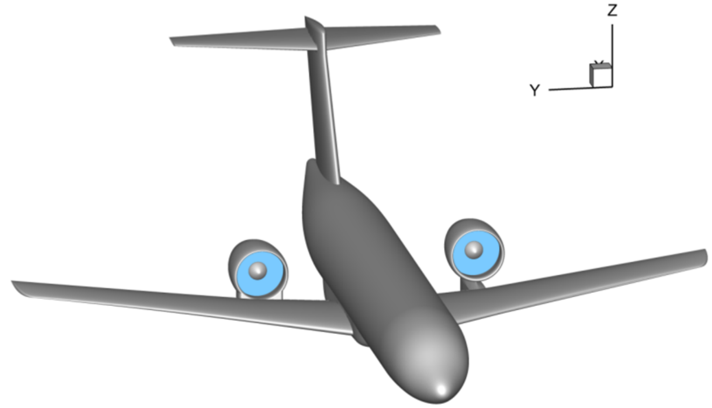


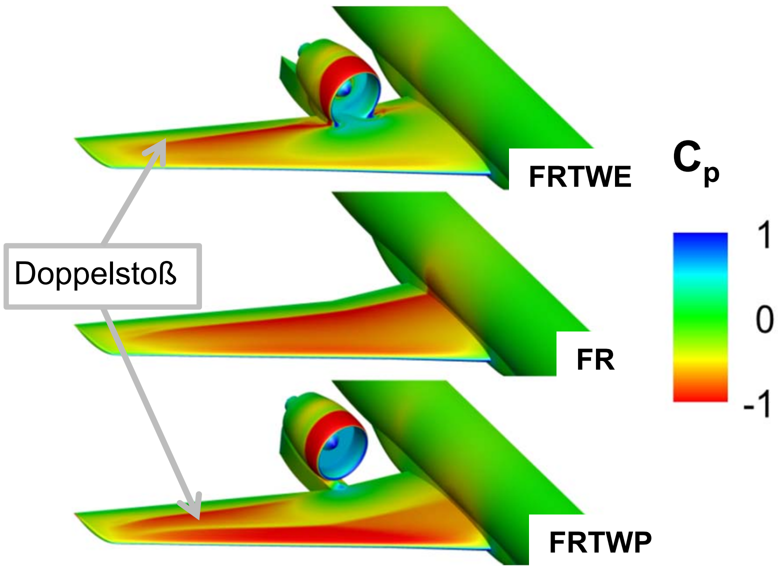


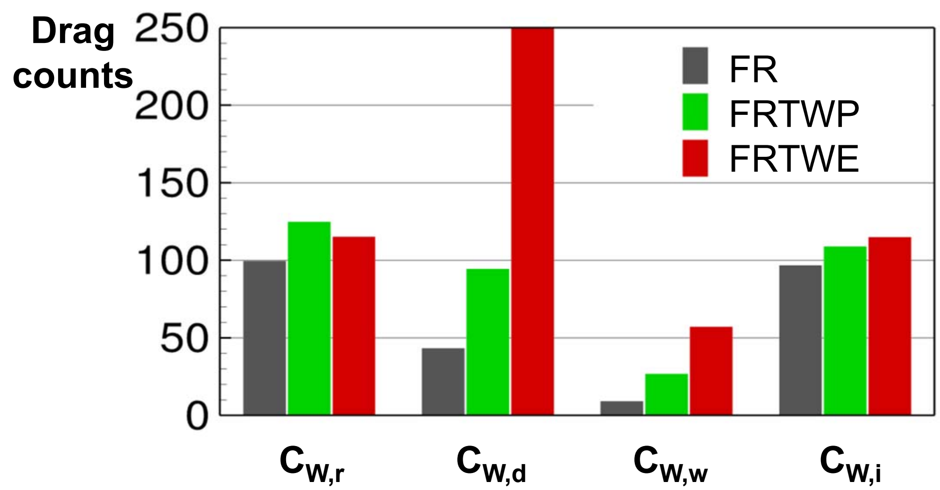
Engine Integration (DFG - CRC880)

<u>Over-the-wing installation of the UHBR nacelle</u>

- Both configurations are comparable in basic effects
- Embedded configuration with slightly reduced friction drag due to smaller wetted area
- Shock on upper wing very sensitive → higher losses without wing redesign

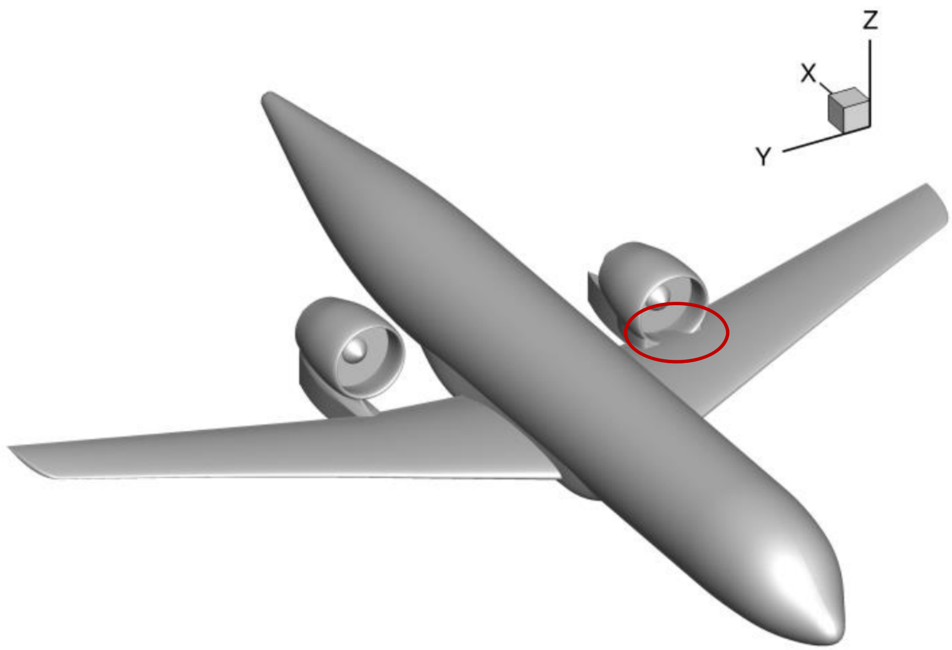


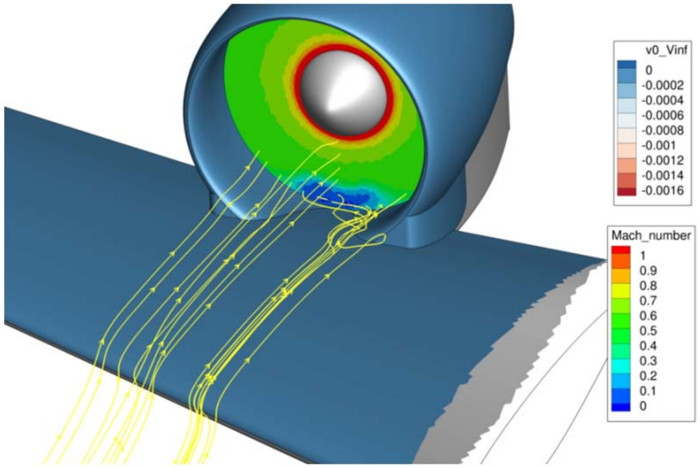




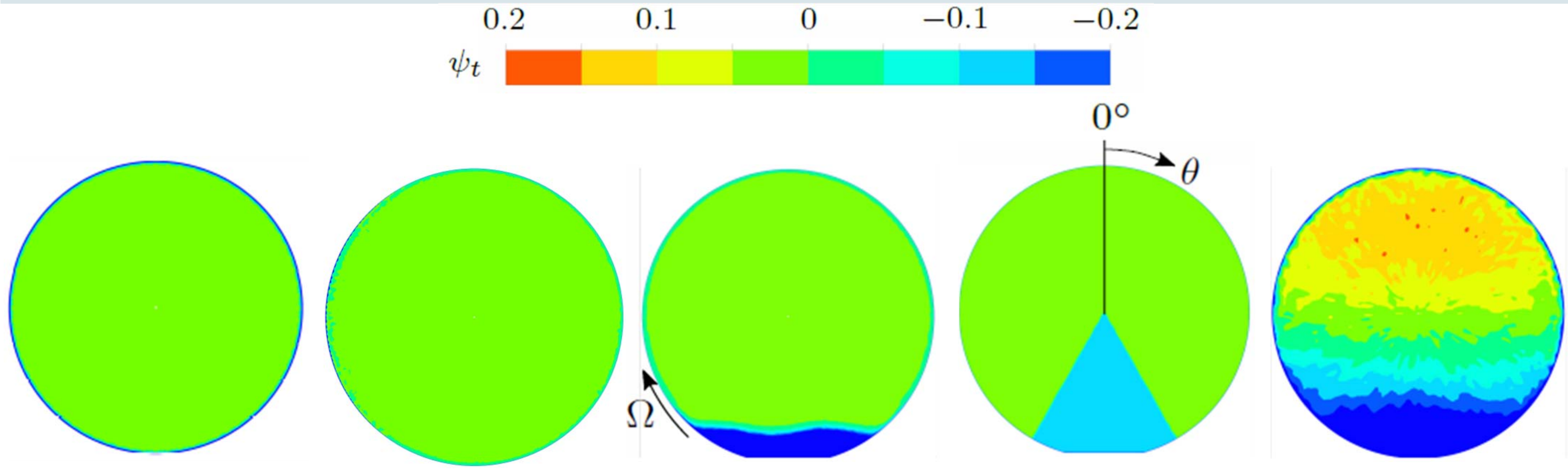
Engine Integration (DFG - CRC880)

- Effects on flow around the wing more severe for the embedded case compare with pylon case due to missing channel flow
- BLI leads to inhomogeneouos nacelle inlet conditiion along the entire operating range





Fan sensitivity (DFG - CRC880)



Clean Cruise „CC“:
- Reference

Aufgest. REF3 „P-REF3ID“: **FRTWP**
- E.g. VFW 614

Teileingebettete REF3 „E-REF3ID“: **FRTWE**

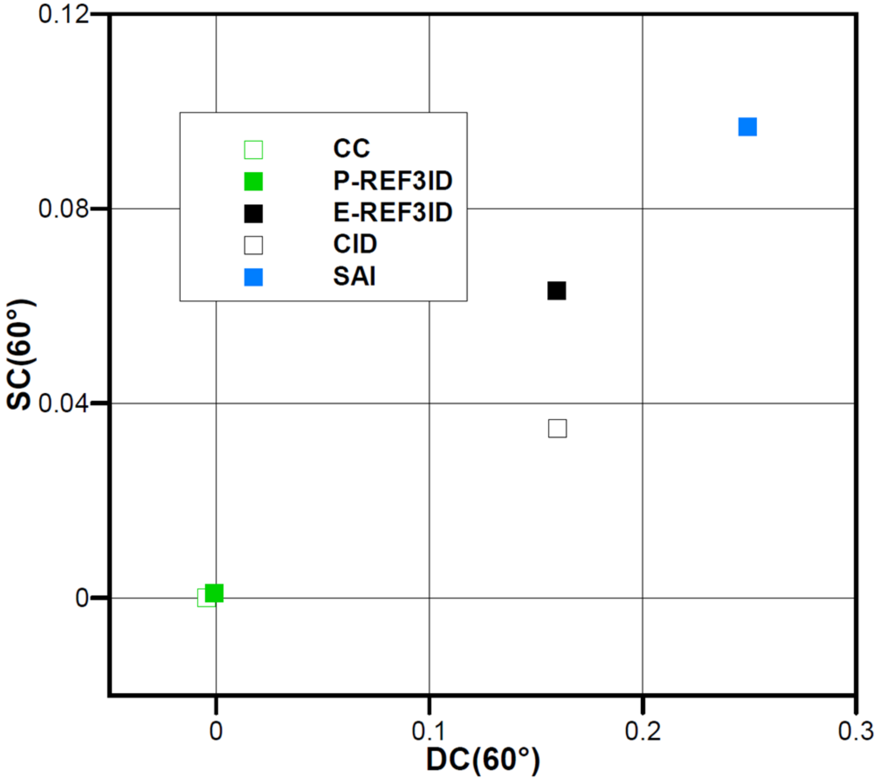
60° Umfangsstörung „CID“:
- „homogenouos“ DC60 as per left E-REF3ID case

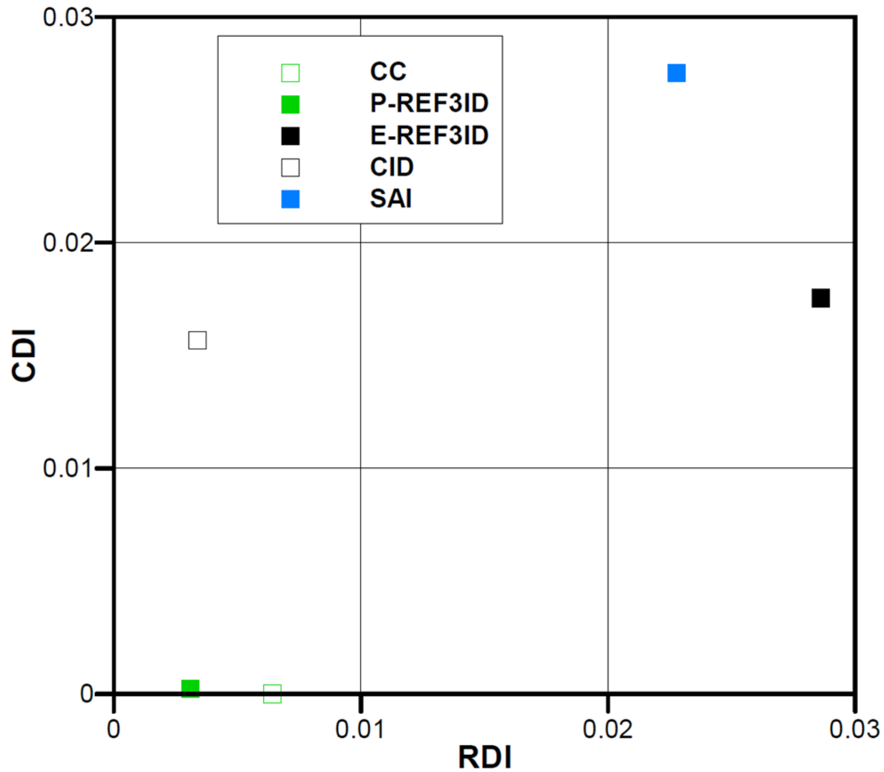
Silent Aircraft Initiative „SAI“:
- skaliert auf Cruise

⇒ Global performane or distortion discriptors might be similar

⇒ But local behaviour (velocities, incidence, DF, ...) can significantly differ

Fan sensitivity (DFG - CRC880)





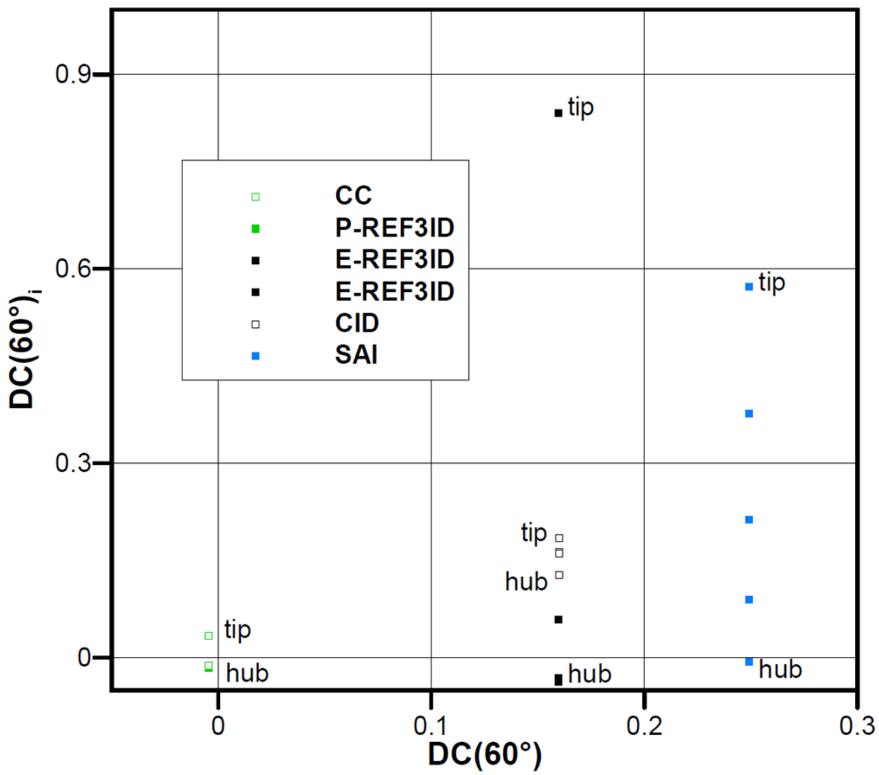
All results at AIP

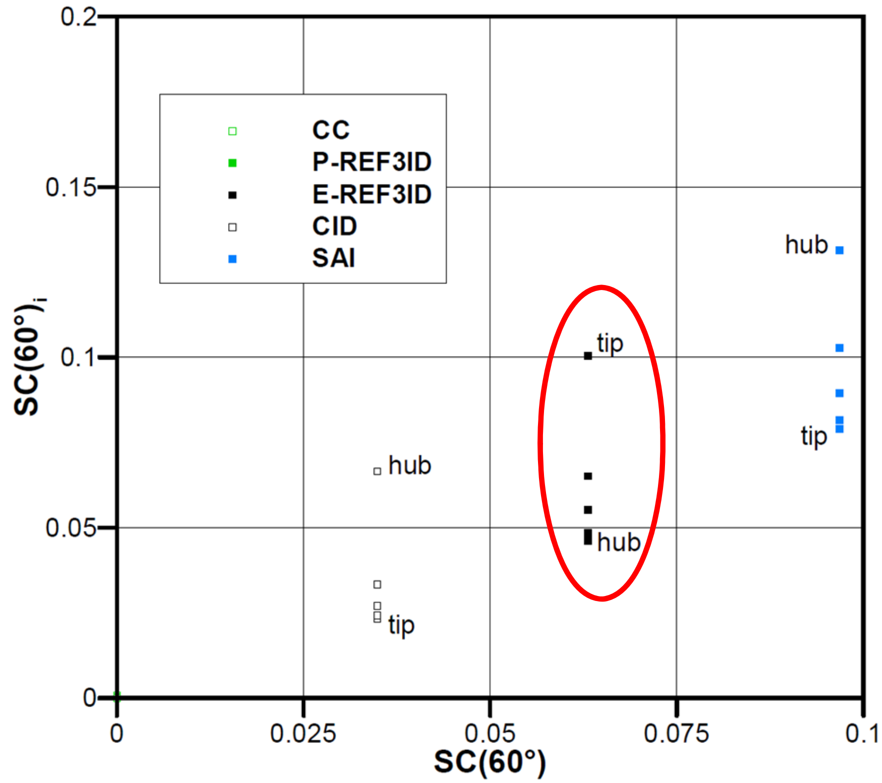
⇒ „SAI“ with highest global distortion level

⇒ strong radial distortion for „E-REF3ID“ (FRTWE)

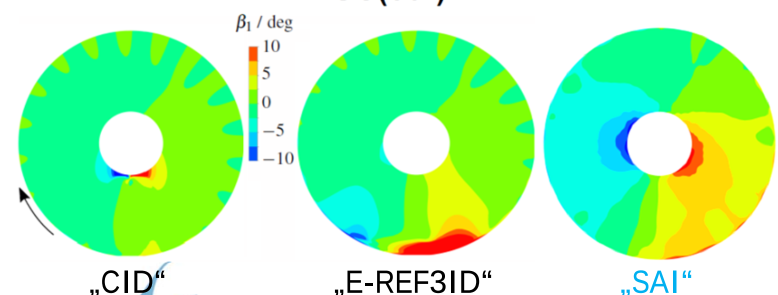
⇒ Generic „CID“ distortion does not show this radial sensitivity

Fan sensitivity (DFG - CRC880)



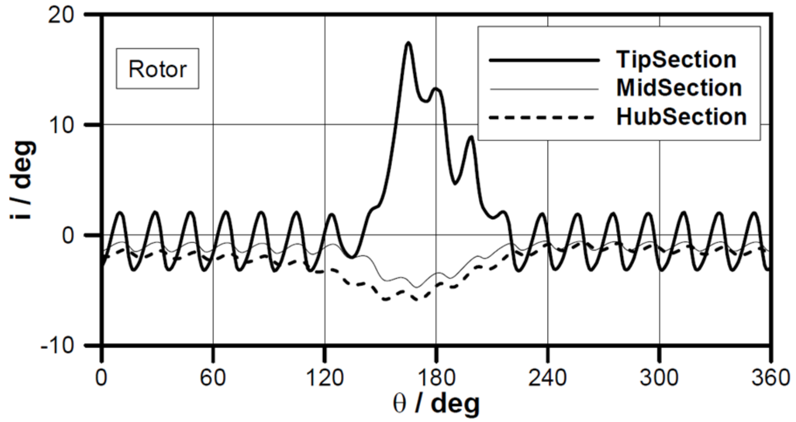


- ⇒ „E-REF3ID“ with highest total pressure distortion at tip
- ⇒ Local swirl distortion shown different behaviour for „E-REF3ID“

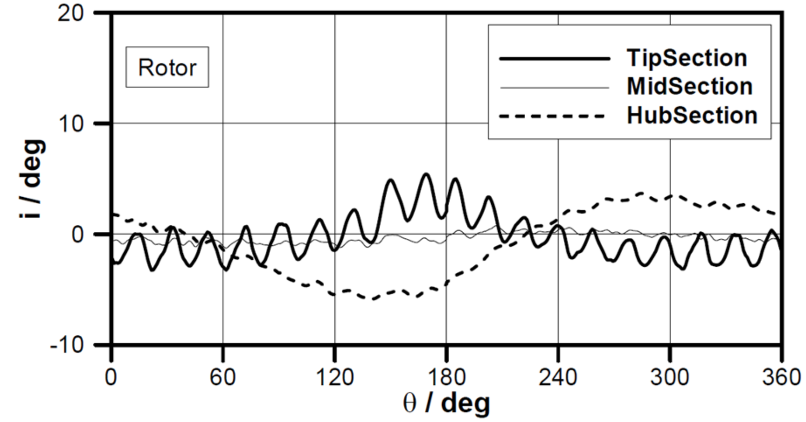


Auswirkungen auf die Rotorströmung

Teileingebettete FRTWE „E-REF3ID“:

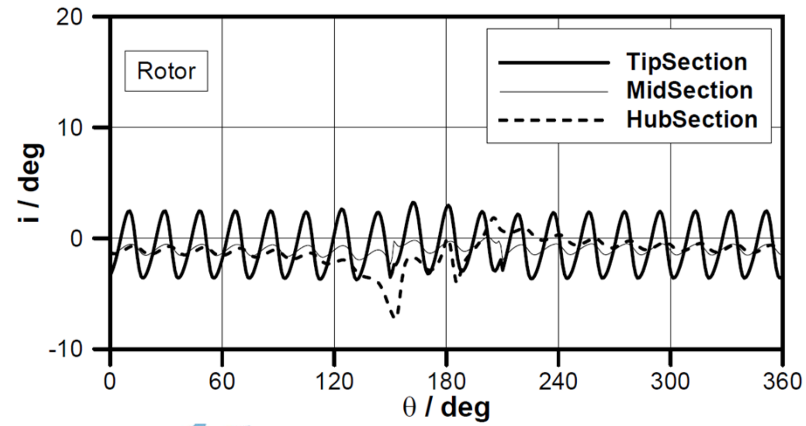


Silent Aircraft Initiative „SAI“:



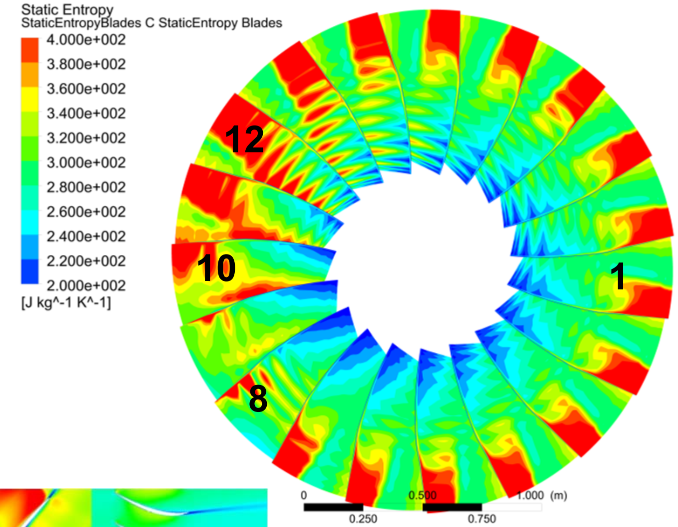
- Änderung des Rotor-Incidences über 60° Umfang größer als 10° für „E-REF3ID“ → hoher Swirl-Winkel im Gehäusebereich
- Rotornaben- und -gehäuseschnitte erfahren gleichmäßigere Incidence-Änderungen bei „SAI“

60° Umfangsstörung „CID:

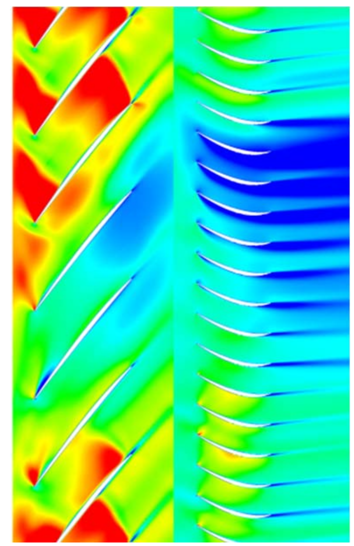


Effekte Rotor / Stator

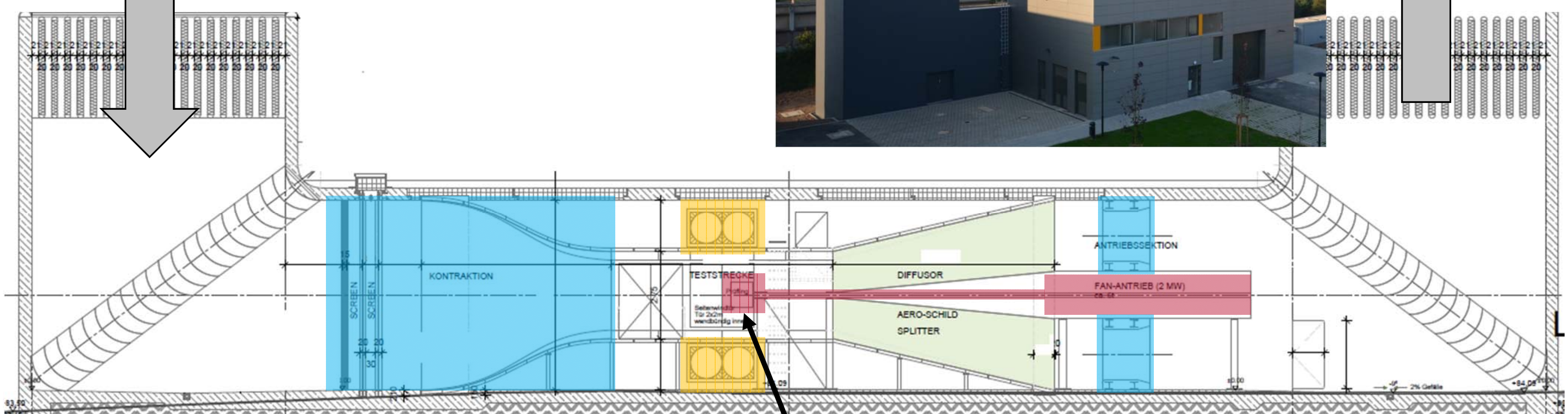
- größten Verluste beim Austritt des Rotors aus dem gestörten Bereich (12)
- starke Veränderung der Stoßstruktur
  → Verblockung im oberen Kanalbereich
  → Umformierung der Strömung (10 -12)
- Rotor-Eintritt in die Störung: co-swirl (8)
  Rotor-Austritt in die Störung: counter-swirl (10)



- Stator mit lokaler (Außenschnitte) Veränderung der Anströmung (8-10)
- Globale (gesamte Schaufelhöhe) Veränderung des Startor-Incidence bei Austritt aus der Störung



Propulsion-Test-Facility (PTF)



Themengebiete

- Ultra-High-Bypass Antriebe mit Mantel
- Einlauf-Fan-Wechselwirkung
- Fan-Verhalten mit Zuströmstörung
- Teilintegrierte Antriebe

Specifications	
Fan diameter	**0.7 m**
Fan pressure ratio	**1.2 – 1.3**
Ma_∞	**0.20 – 0.25**
Re_{Model} / Re	**0.3**

Propulsion-Test-Facility (PTF)

Propulsion-Test-Facility (PTF)

<u>Aspirated Intake Tests</u>

- Aspirated-Intake-Rig (ASI) → In-house designed and manufactured
- Fan is located far downstream → no interaction between fan and nacelle flow
- 7500 rpm, 170kW
- In-house rotor design:
  - Conventional compressor blades with N/ 65-series thickness distribution

<u>Measuring Equipment</u>

- Measuring section with 12 rakes at the fan face area → 138 total and static pressure taps
- Internal and external lip -> 6 sections x 42 static pressure taps

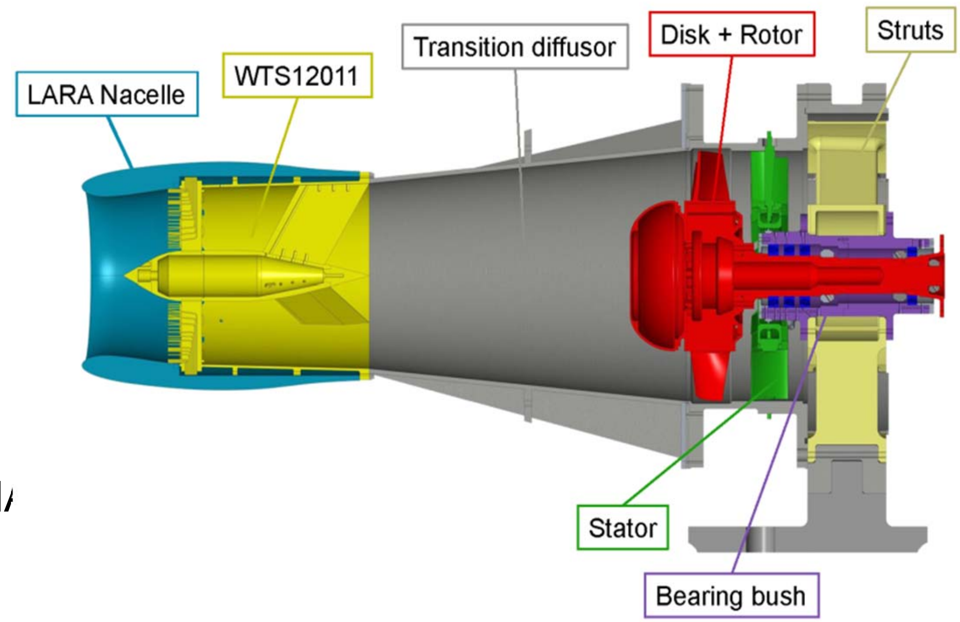
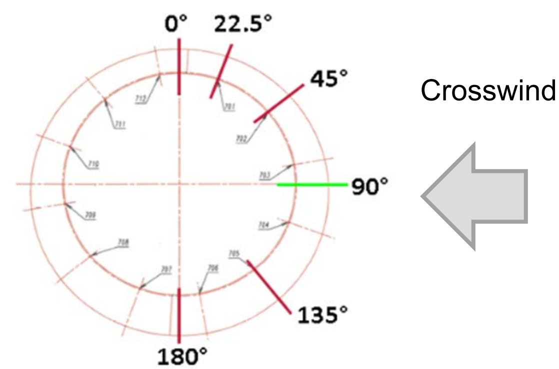
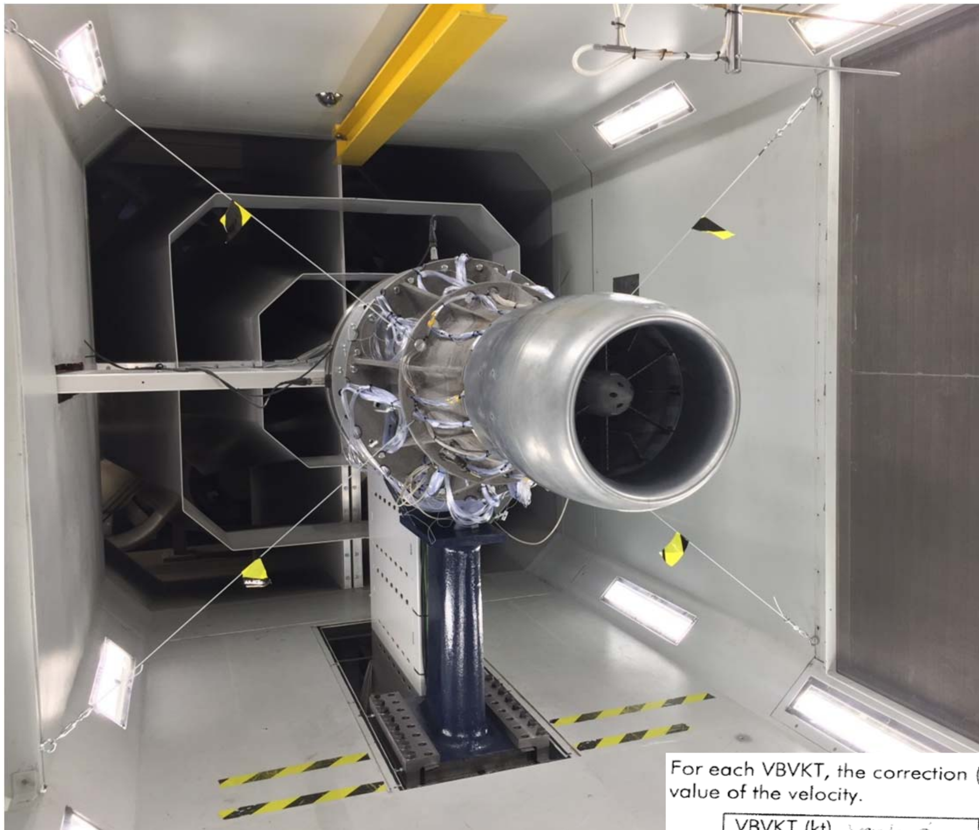


Fig. 8: Cross section of the ASI-Rig



Propulsion-Test-Facility (PTF)



LARA crosswind campaign

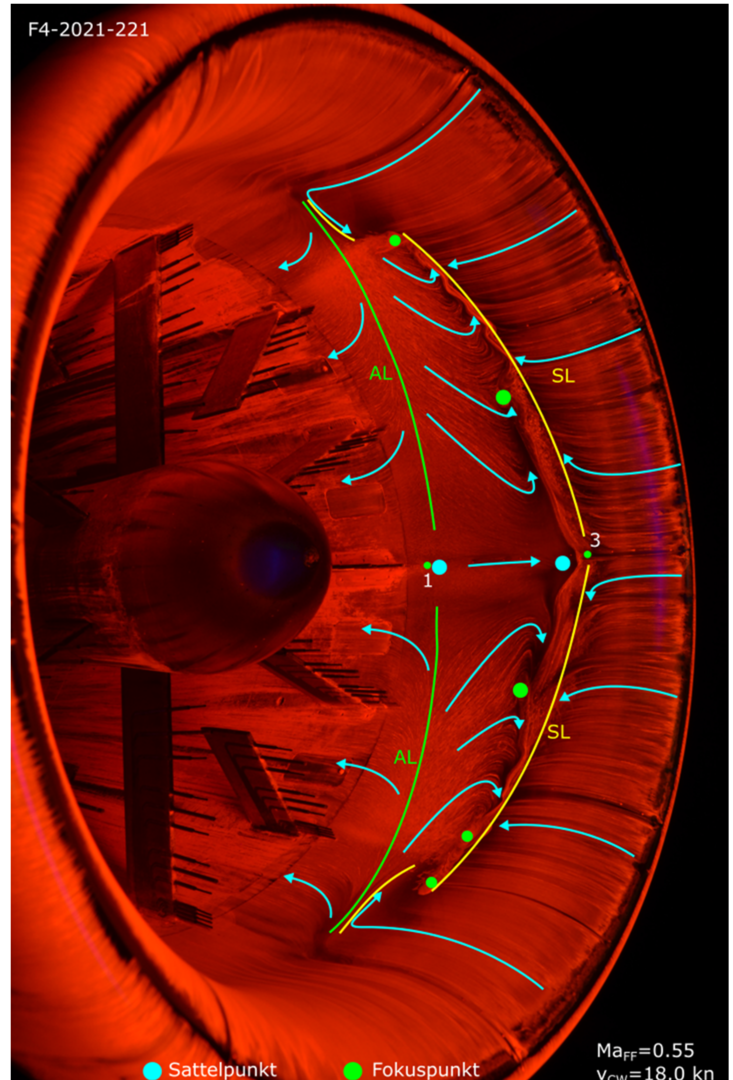
- Generating crosswind equivalent conditions inside PTF
- Evaluation of intake pressure distributions
- Evalutation of fan face pressure distributions
- Comparison to existing LARA data and CFD

- **Ma_2 = 0.45** (approx. 70% speed)
- **v_{CW} = 11.3 m/s (22 kt)**

For each VBVKT, the correction (rounded up at 0.5 kt) is given in the following Table together with the corrected value of the velocity.

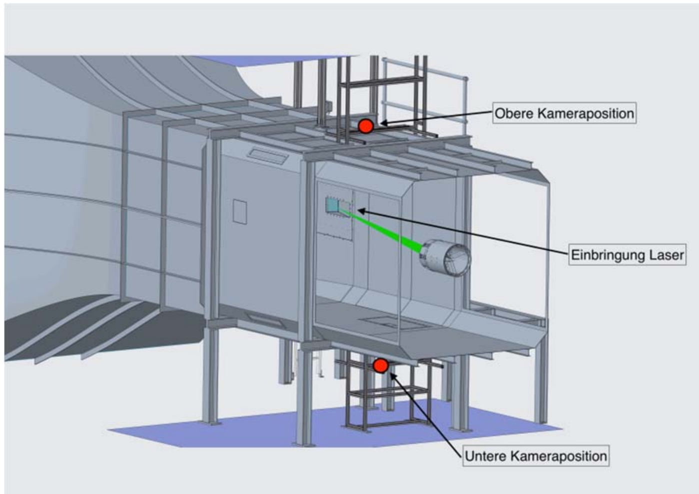
VBVKT (kt) venturi → falsch	10	15	20	25	30	35	40	45	50	46
DV (kt)	4.5	5.5	6.5	7.5	8.0	8.0	7.5	6.5	4.5	
Corrected velocity (kt)	5.5	9.5	13.5	17.5	22.0	27.0	32.5	38.5	45.5	40

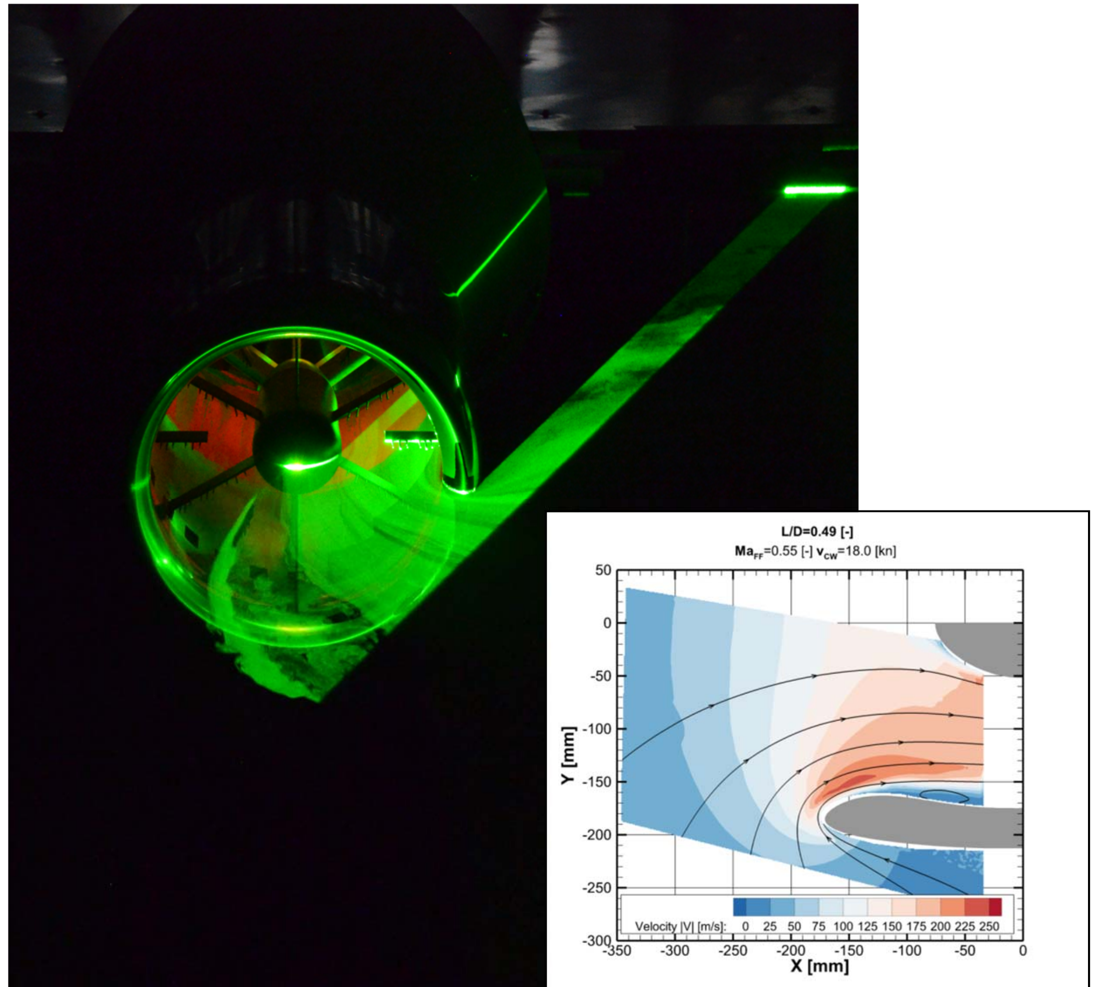
IRIS – Intake Aerodynamic Distortion Study



Aspirated short intakes
in cross-wind conditions

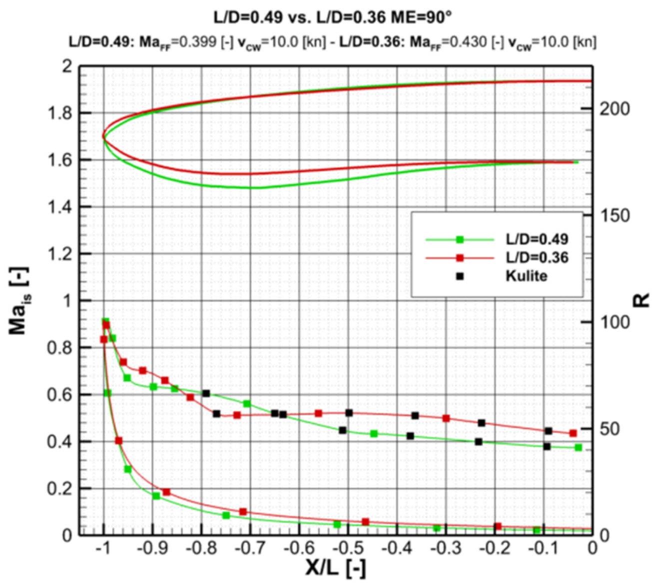
IRIS – Intake Aerodynamic Distortion Study

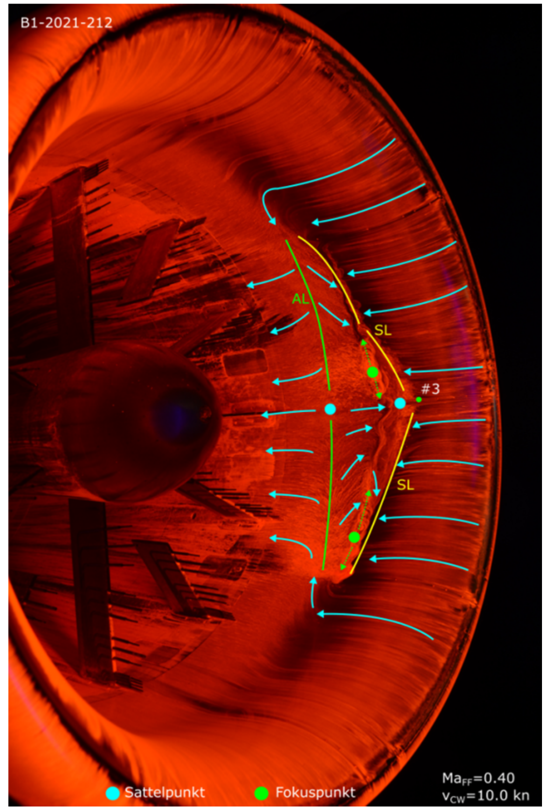


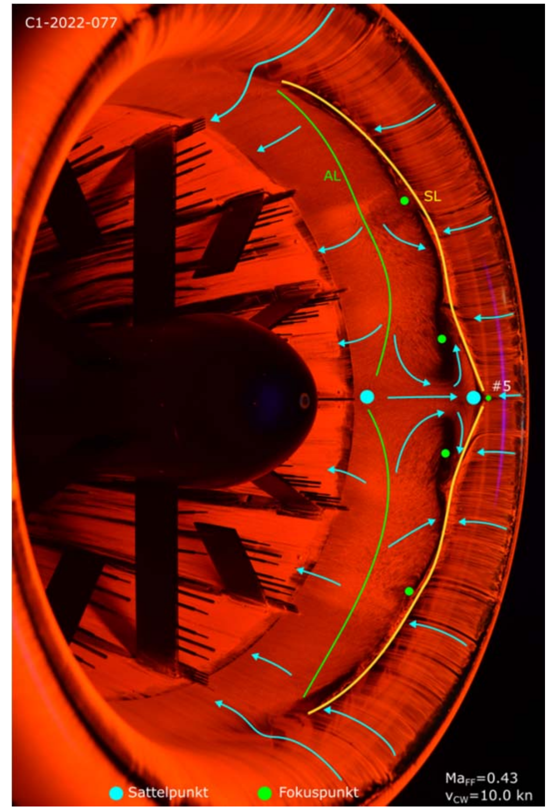


Aspirated short intakes in cross-wind conditions

IRIS – Intake Aerodynamic Distortion Study

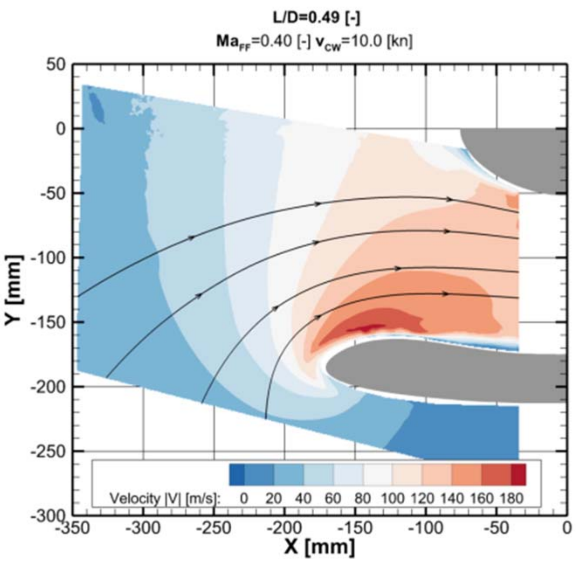


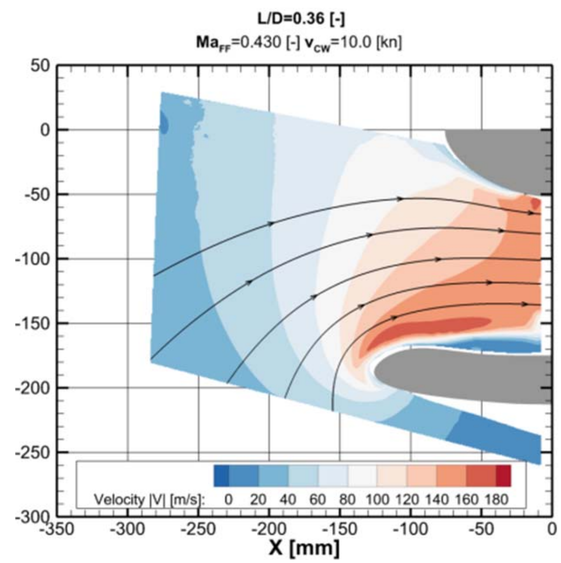


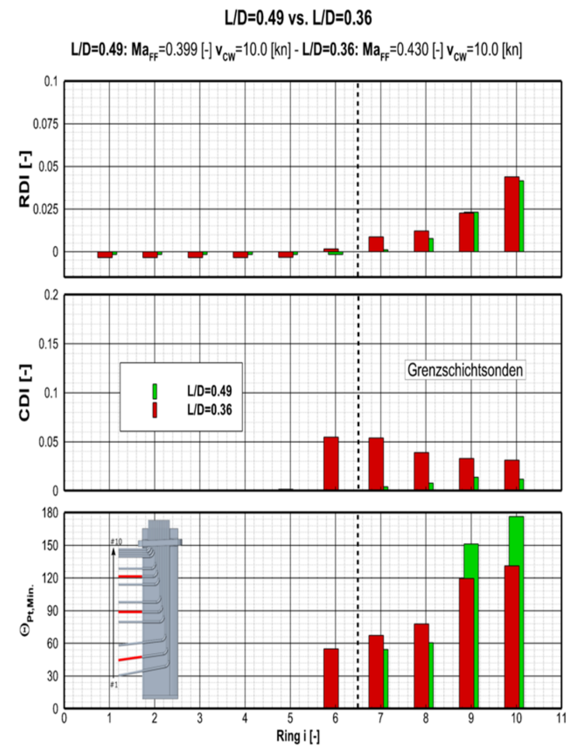


- Cross-wind behavior
- Static pressure
- Oil flow visualization
- DC60, RDI, SCI

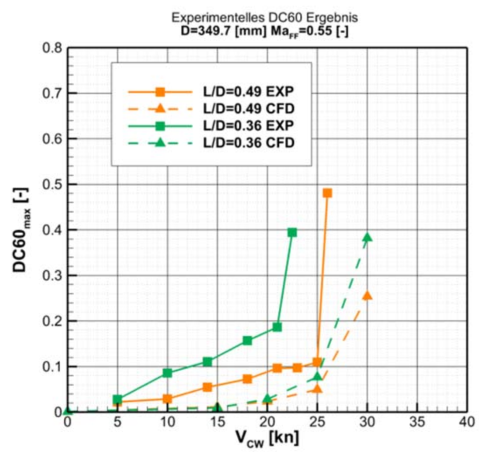
IRIS – Intake Aerodynamic Distortion Study





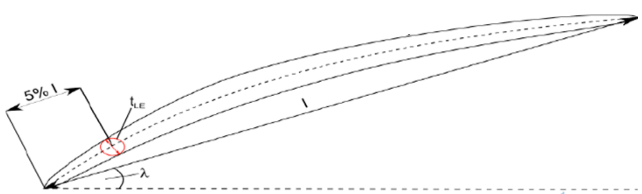


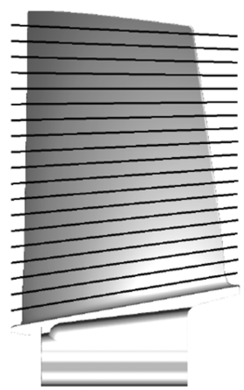
- Cross-wind behavior
- PIV
- DC60, RDI, SCI



SFC Optimized Maintenance

- Parametric geometry analysis for blades from service
  → IFAS-Analyzer for statistical analysis
- Re-Engineering of sectional pofile parameters
- Analysis of different types of blades (so far Fan, NDV, HDV, BLISKs)
- Re-Engineering allows to generate „synthetic deterioration“





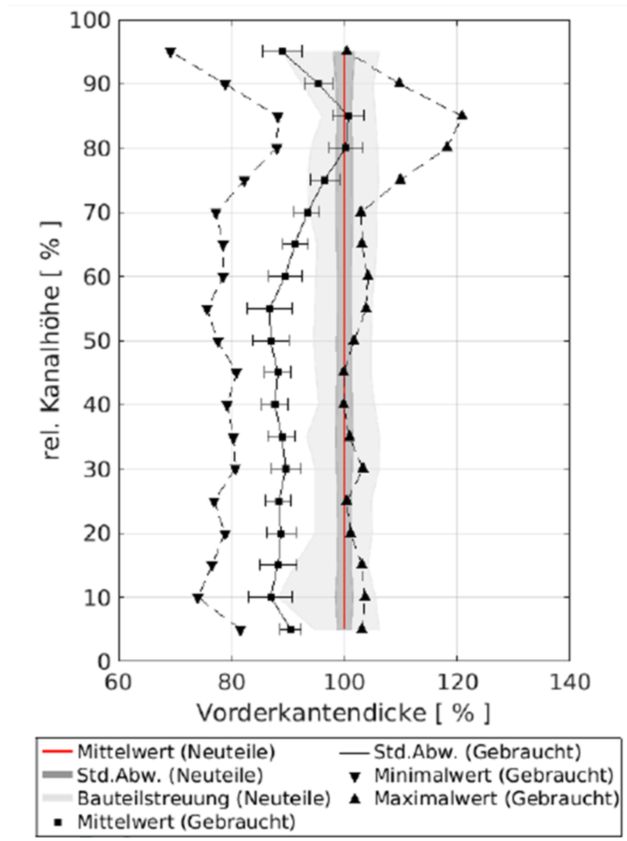


Abb. 8: Radialverteilung von d_{VK} in Rotor 4

SFC Optimized Maintenance

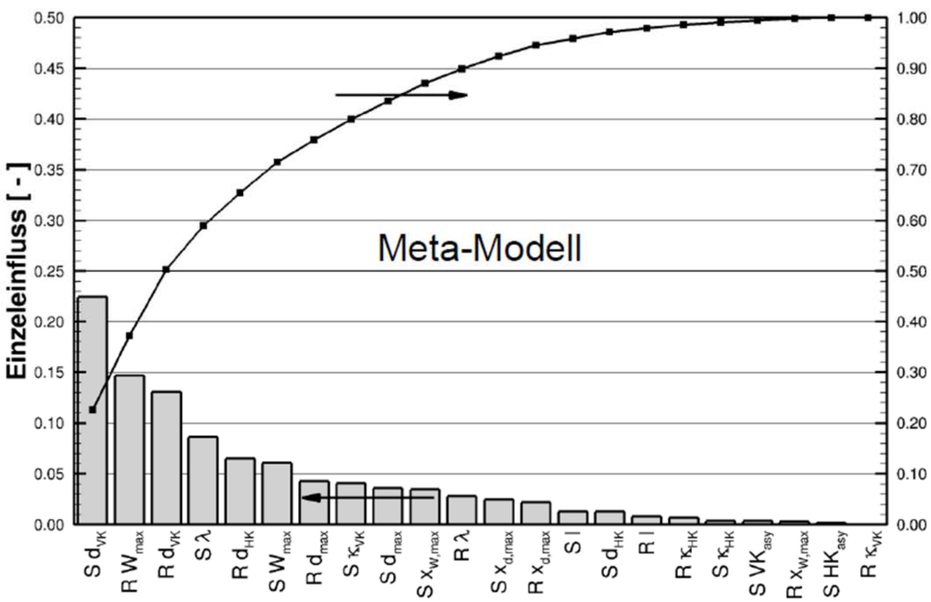


Abb. 22: Pareto-Front von η_{poly} der Frontstufe (Meta-Modell)

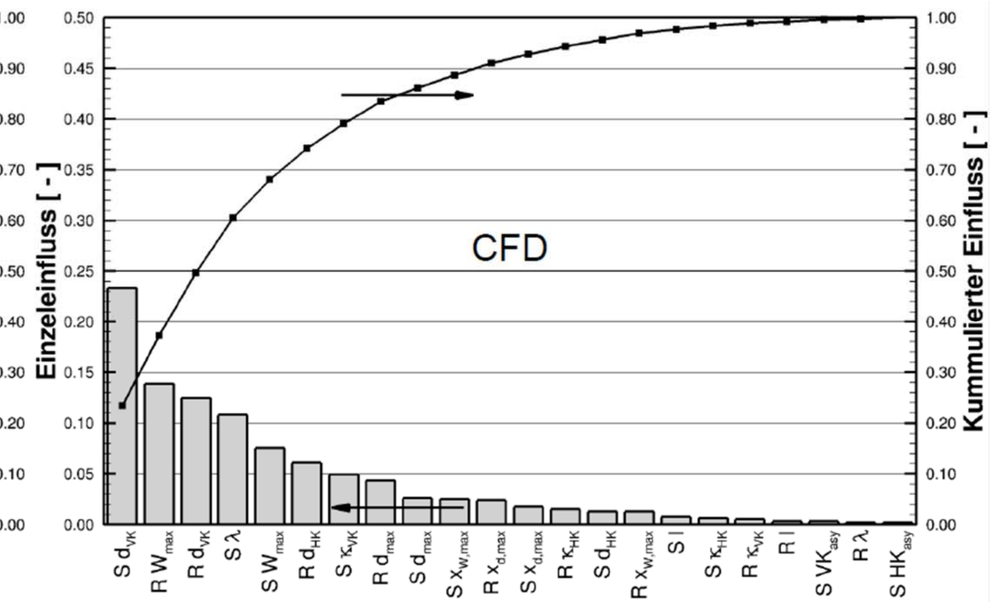


Abb. 23: Pareto-Front von η_{poly} der Frontstufe (CFD-Modell)

SFC Optimized Maintenance

Ziel:

- Erstellung eines aerodynamischen Modells des HDV für den gesamten Betriebsbereich

Nötige Arbeiten:

- Kalt-heiß-Rechnung der Schaufeln und des Ringraums für betriebsnahe Geometrien
- Messung der VSV-Winkelabhängigkeiten für spätere Justierung des Betriebspunktes
- Erstellung eines vollständigen CFD-Modells inkl. aller notwendigen Einzelheiten

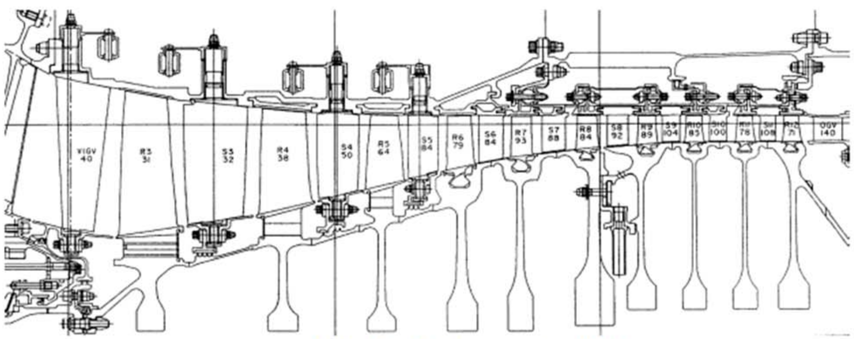


Abb. 13: Zeichnung des HDV

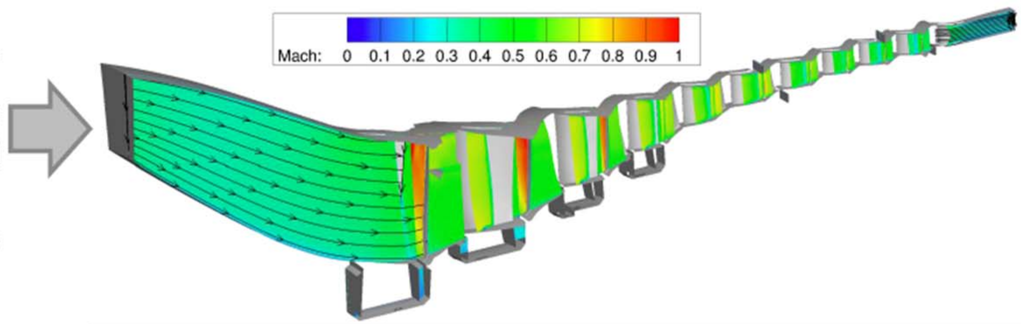
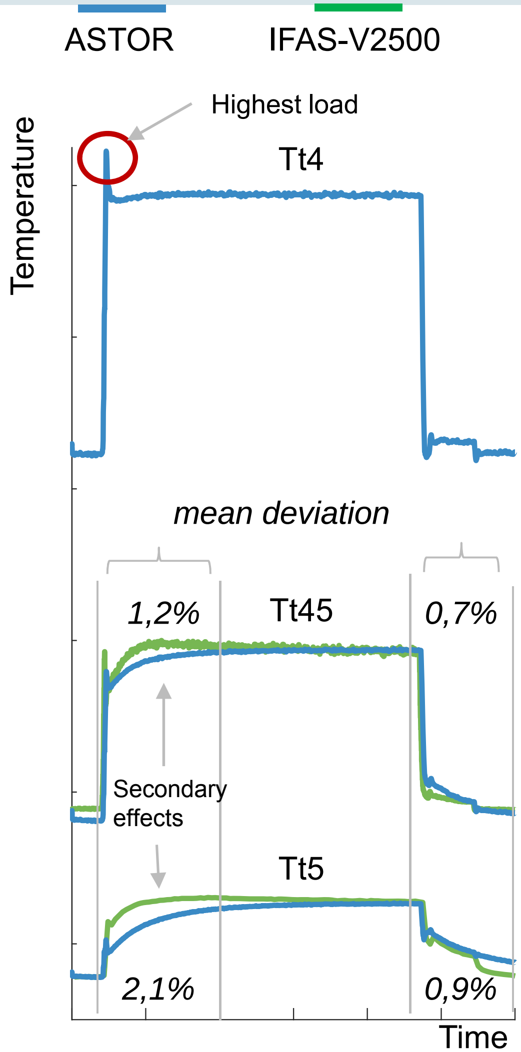
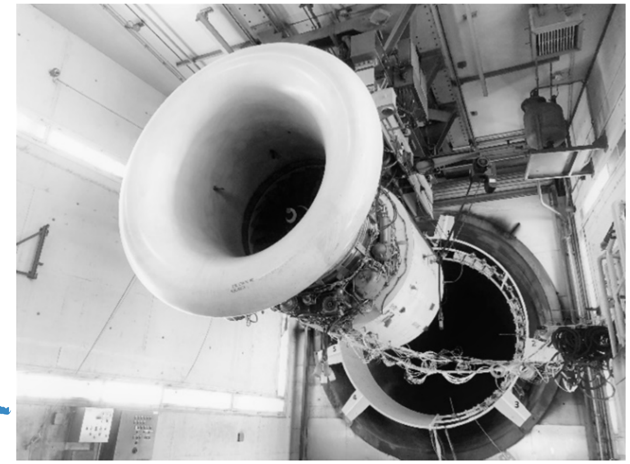


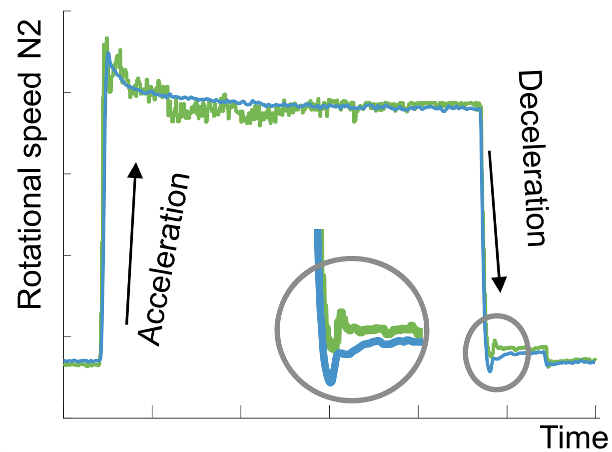
Abb. 14: CFD-Modell des HDV mit Lösung

V2500-A1 Engine testing





IFAS research jet engine



Technische Daten

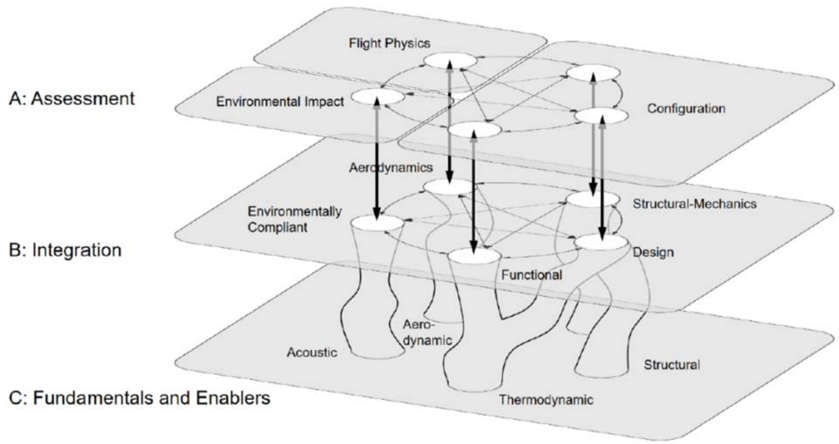
- Zwei-Wellen-Zweikreis
- BPR=5,4; OPR=35,8;
- EIS: 1989;
- FADEC;
- Zusatzinstrumentierung;
- Telemetrie

SynTrac - Synergies of Highly Integrated Transport Aircraft

Joint initiative between Uni Stuttgart and TU Braunschweig for future SFB

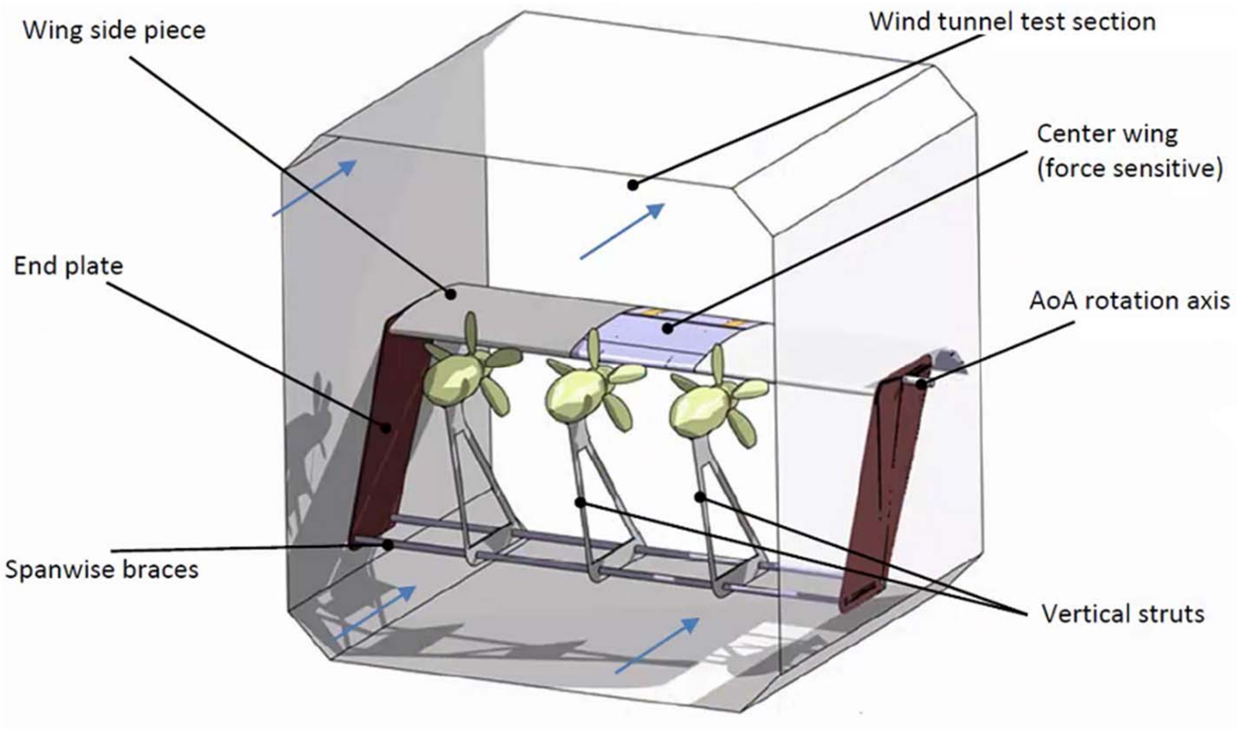
Goal: Exploiting the potential for improving the environmental impact through multidisciplinary basic research

via:
- Increase of entire aircraft system efficiency
- Reduction of gaseous and vapour emissions
- Reduction of acoustic emissions



focus ISM and IFAS:
- Experimental/numerical analysis of loss behavior for closely coupled propulsion
- Aerodynamic couplings of propulsion, airframe and control surfaces
- Functional Integration of Propulsors and waste heat management
- Exhaust flow control
- Inlet flow control

CICLOP - Characterization of the Interaction between wing and CLosely Operating Propeller

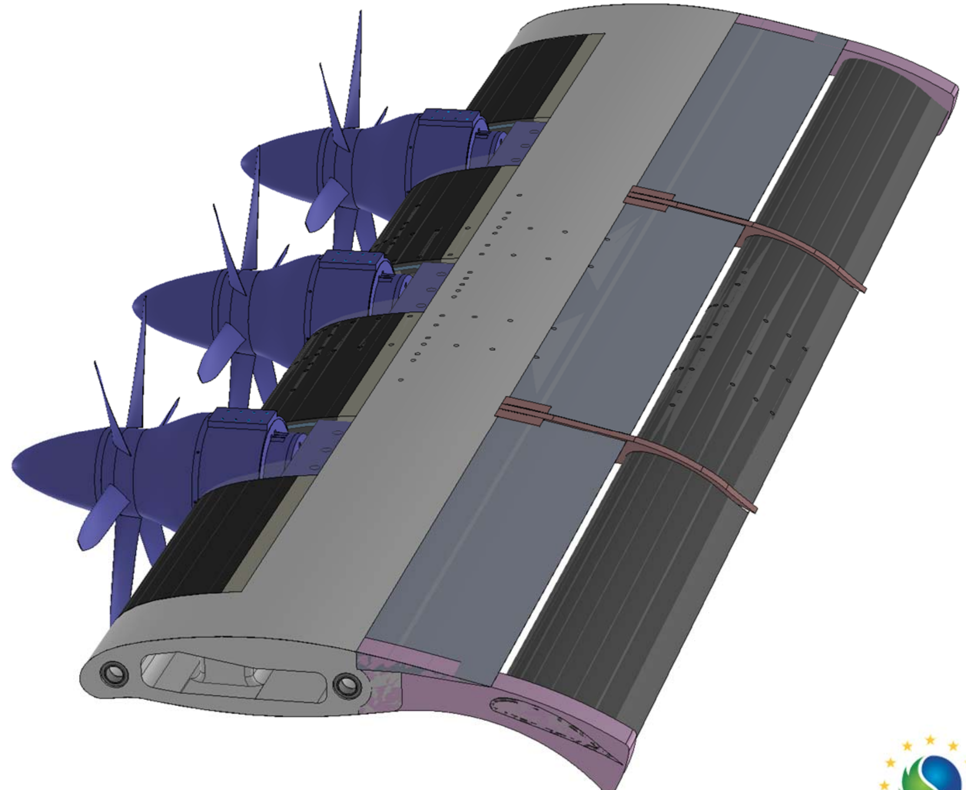


- CS2 – JU
  (TM: CIRA;
  Industrial coord.: Leonardo
- partner: ISM
- 2020 - 2022
- wing aerodynamics with distributed propulsion (3 props)
- 2 prop diameter / 2 motors
- WT up to 55 m/s

Clean Sky 2
JOINT UNDERTAKING

DISPROP - Aerodynamic and aeroacoustic modeling of closely operating propellers for DIStributed PROPulsion

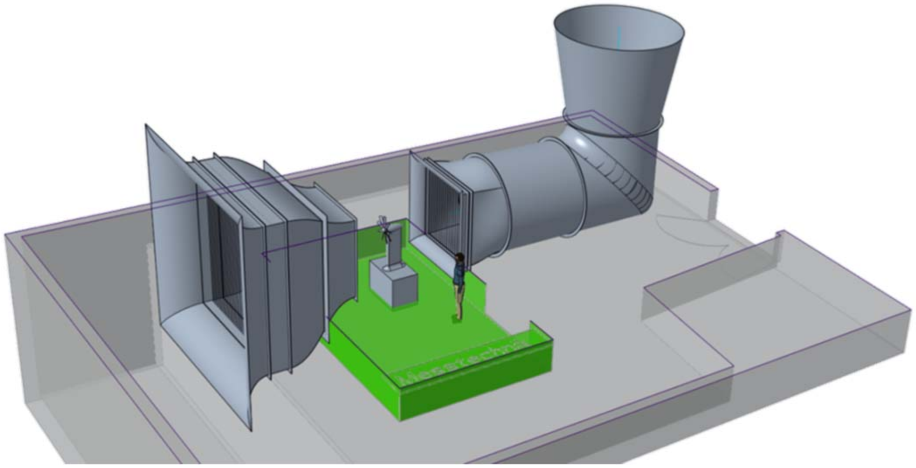
DISPROP



- CS2 – JU (Airbus / TU Delft)
- partner: ISM; TU Berlin; TU Stuttgart; Leichtwerk; DLR
- 2020 - 2023
- wing aerodynamics / acoustics with (3 props)
- small WT experiments @ TU Berlin (Q1/22)
- large WT experiments @ DNW-NWB (open & closed section)

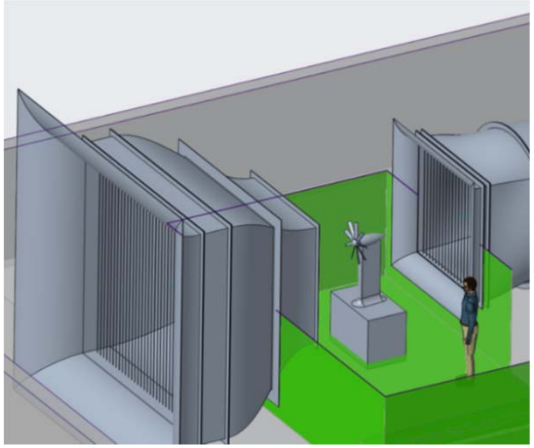
Clean Sky 2 JOINT UNDERTAKING

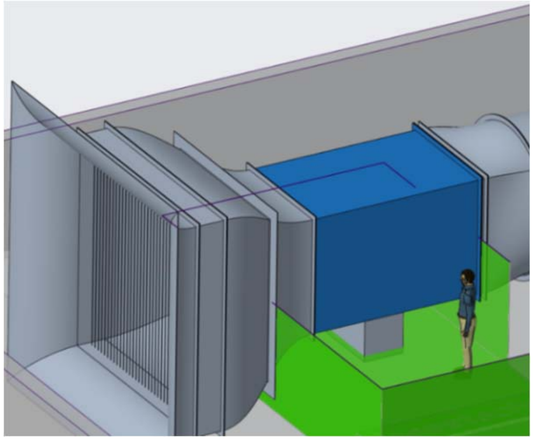
Flybots

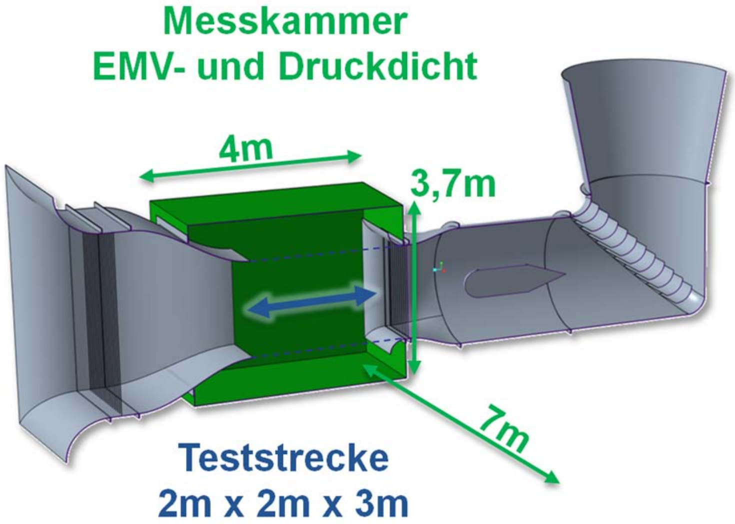


- UAV Testing Infrastructure
  @ Forschungsflughafen
- Cooperation with DLR, TU Braunschweig
- Funding (Lower Saxony) for infrastructure

Flybots – TU Braunschweig

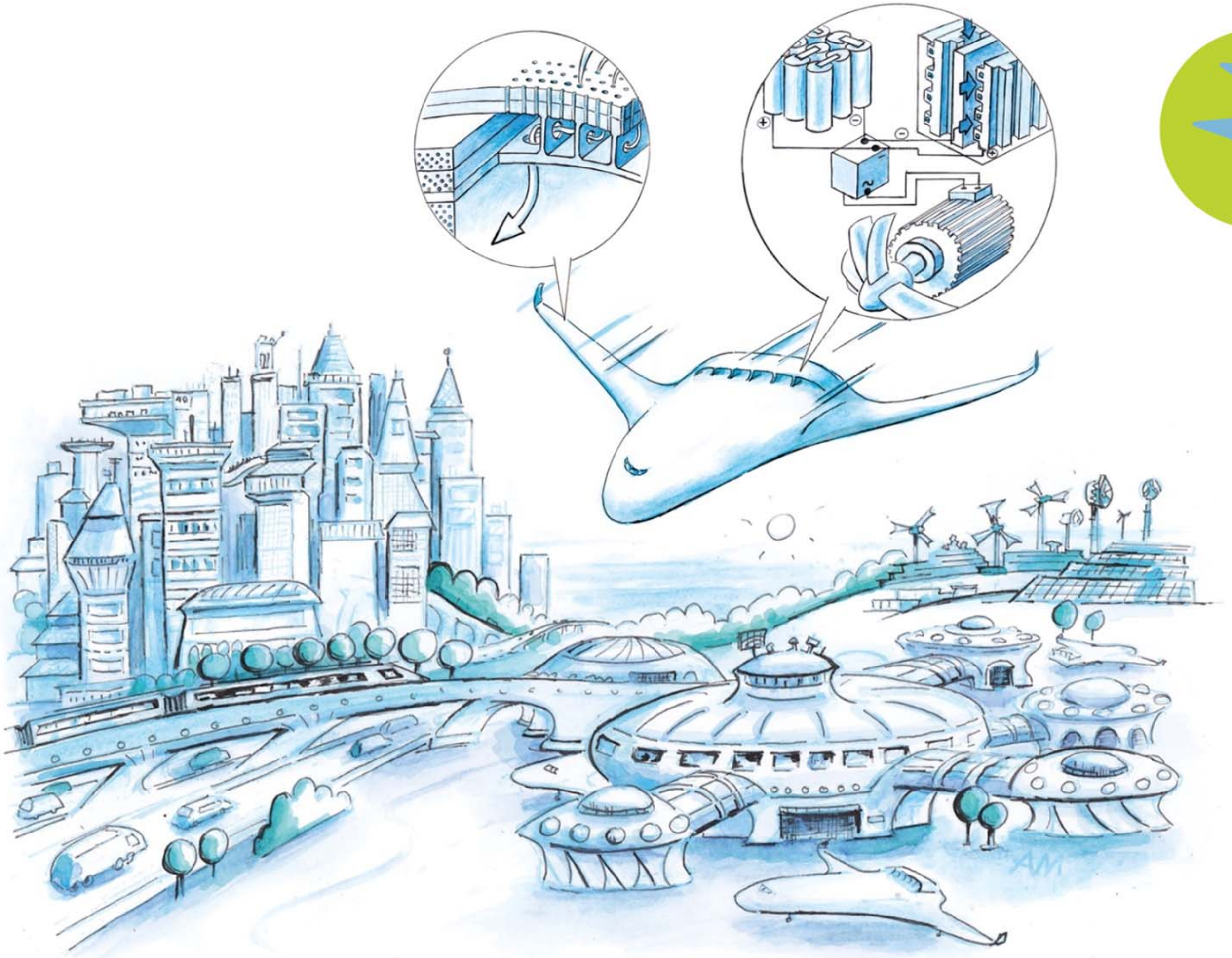






- Aerodynamic propulsion test rig with simultaneous measurement of EMC (electromagnetic compatibility)
- UAV/drones in full-scale design Test under full load conditions
- Open / Closed Aerodynamic test section
- Flow velocities up to 35m/s
- Ø0.7m propeller diameter
- EMC cage with approx. 100m³ volume
- Start: 05/22
- Commissioning until 06/24

SE²A – Sustainable and Energy-Efficient Aviation



SE²A

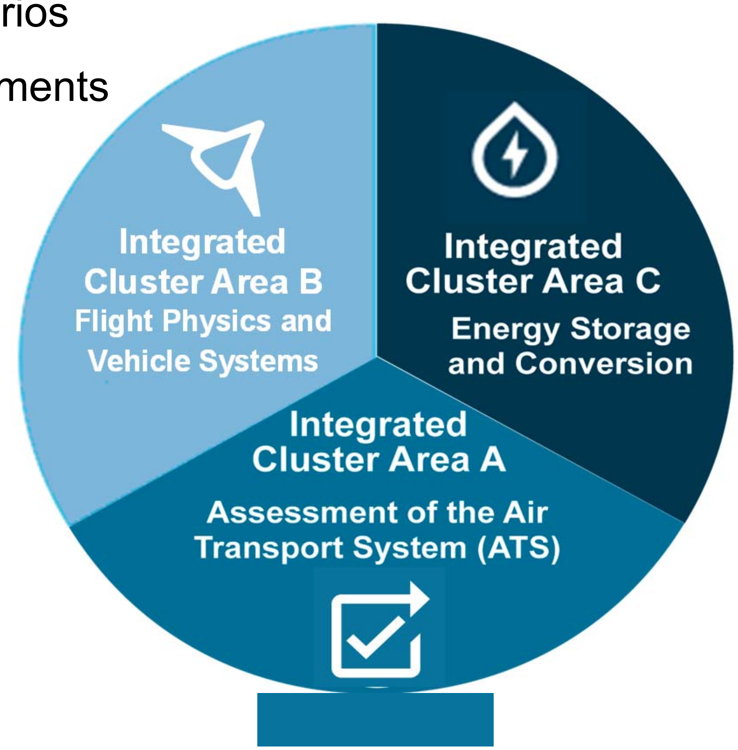
Technische Universität Braunschweig

IFAS Institut für Flugantriebe und Strömungsmaschinen

EXC 2163 – Sustainable and Energy Efficient Aviation – SE²A

- Innovations and designs for significantly reducing the carbon footprint and noise
  (not leaving other emissions out of focus)
- Tools and criteria for decision-making in future scenarios
- Identification of key research and technology requirements
- Validation of fundamental approaches
- Recognition of prospective game-changing technologies and transfer into aviation

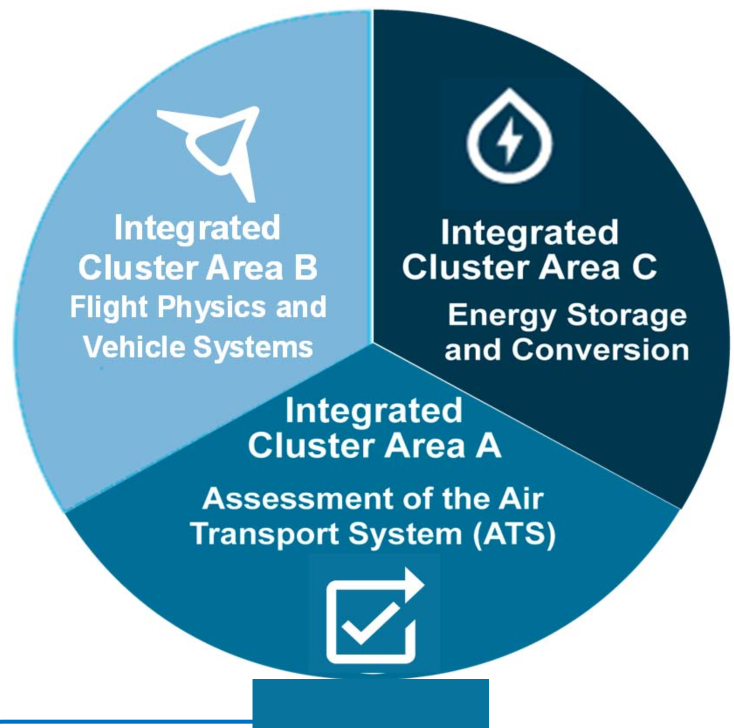
- Status (2021):
  32 Research Projects
  58 Pis
  4 JRG
  57 Doctoral Researchers



SE²A – Platform for interdisciplinary cooperation in aeronautics

SE²A

Aeronautical Sciences
Aerodynamics
Aeroacoustics
Aero engines
Aircraft structures
Aircraft systems
Air traffic management
Flight experiments



Power, Process & Industrial Sciences
Battery design and prod.
Electrosynthesis
Fuel cell
Combustion
Turbomachinery
Electrical energy conversion
Hybrid structures

Economics & Social Sciences
Multi-criteria evaluation
Scenario analysis
Operations research
Life-Cycle assessment
System dynamics
Mathematical optimization
Total cost of ownership

Leibniz Universität Hannover
DLR
PTB
TU Delft
hannover airport
Hochschule für Bildende Künste Braunschweig

Technische Universität Braunschweig

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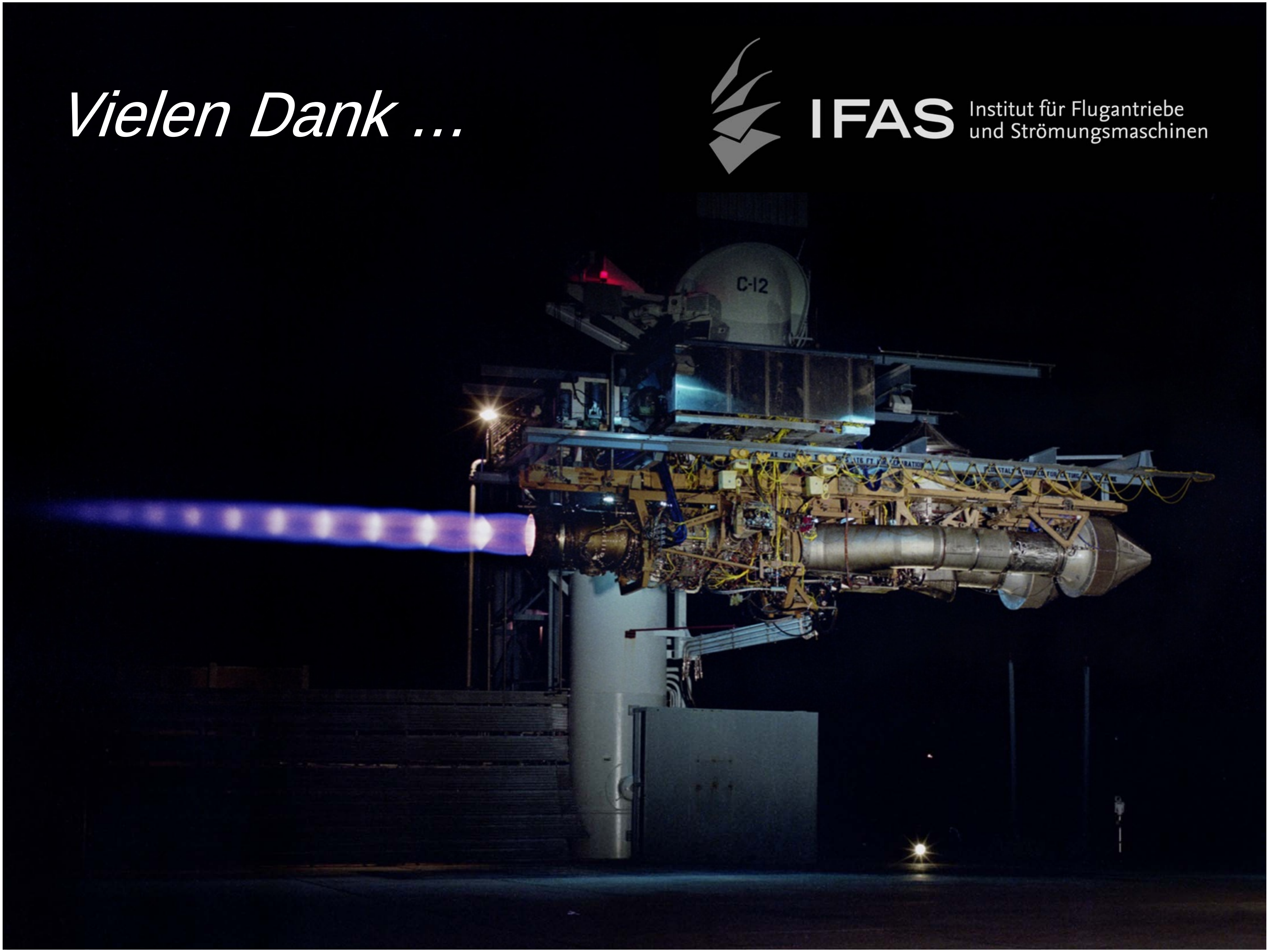

Vielen Dank ...
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C-12