Experimental Testing Environment for coupled Fan Intake Interaction of UHBR Propulsors

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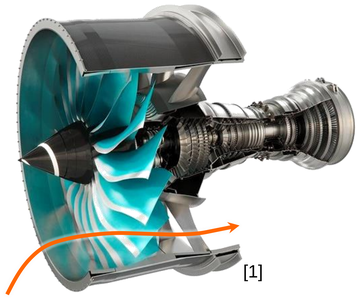
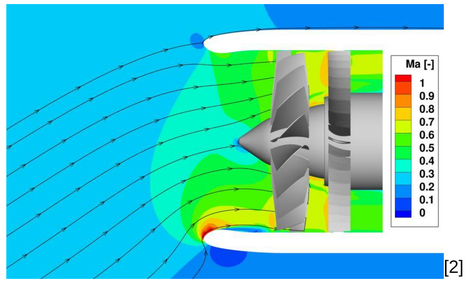
Motivation

Improvement of the **propulsive efficiency** via larger bypass ratios
↳Consequences: Larger, heavier nacelles with higher drag
↳Counter measures: Reduction of axial length of intake geometry
↳**Focus: Closer fan and intake coupling and interaction, Off-design operating points**



[1]

Cross wind induced flow separation in modern ultrahigh bypass ratio (UHBR) engines (e.g. Rolls-Royce UltraFan).



[2]

Numeric calculation of fan intake interaction with modern intake geometry under distorted inflow.

Wind Tunnel

- Combination of two wind tunnels
- Powered fan stage
- Test section dimensions: 2.4 x 2.4 x 8 m

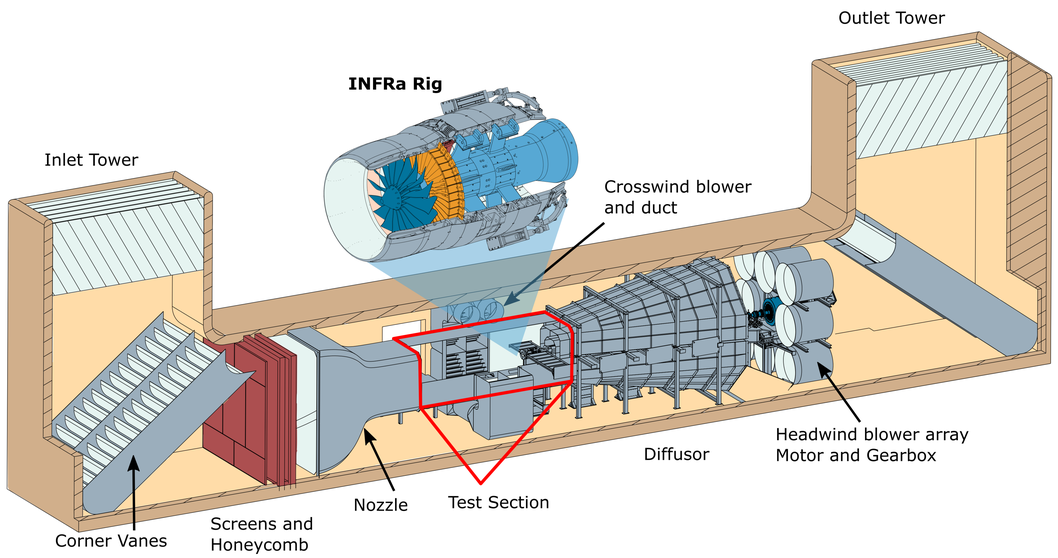


Fig.: Propulsor Test Facility (PTF) with test rig and main components

Cross Wind Concept

Head Wind:	1,0 MW	Ma_{max} = 0.2
Cross Wind:	0,2 MW	$v_{CW,max}$= 40 kts
Powered Rig:	2,0 MW	11.000 rpm

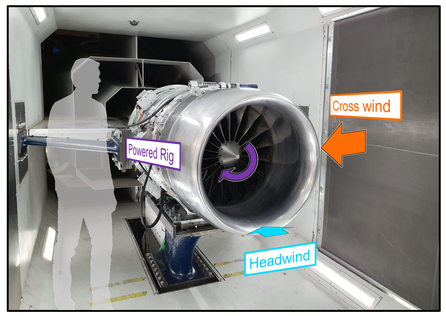
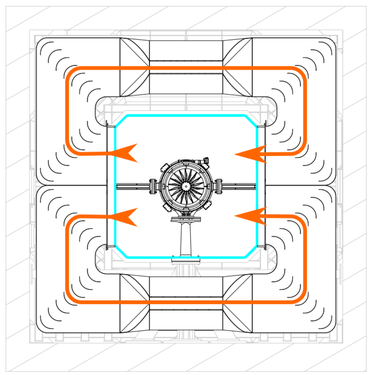


Fig.: Integrated Nacelle Fan Rig assembly in test section



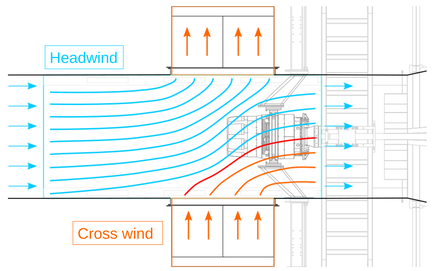
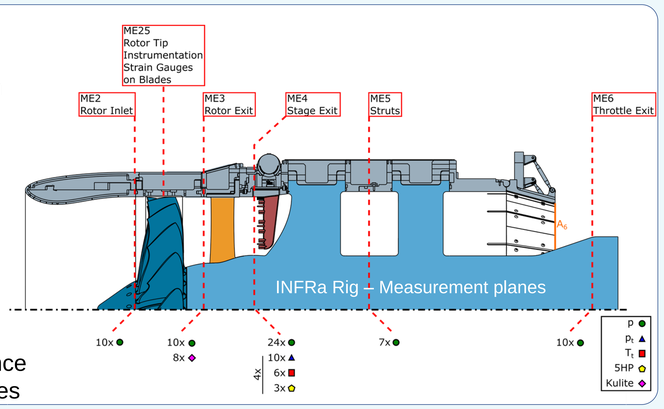


Fig.: Cross wind scheme, vertical and horizontal cut

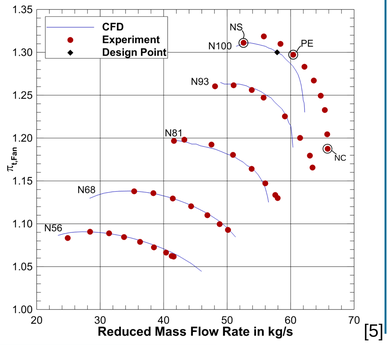
Test Rig

- Modern UHBR design
  - Scale 1:3
  - π_{FAN} 1,32
  - BPR ~17
  - Fan Ø 650mm
- Modular concept
- Adjustable throttle [4]
- Instrumented nacelle
- Rotor telemetry
- Tip timing and clearance
- Traversable wake rakes



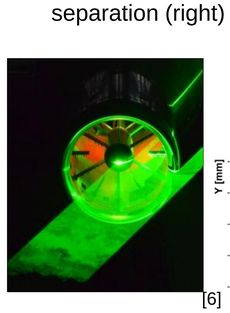
Experimental Results

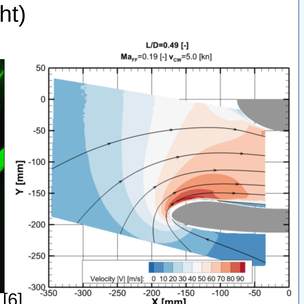
- Complete compressor map [3,5]
  - CFD vs. Experiment
  - Undistorted flow



[5]

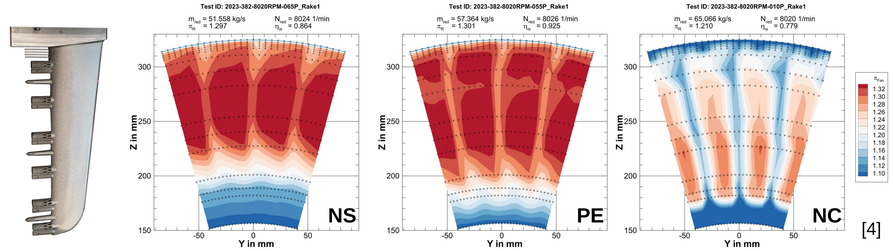
- PIV analysis of intake distortion [6]
  - Photo of setup during operation (left)
  - Measurement result of windward intake contour with cross wind induced flow separation (right)





[6]

- OGV wake measurement at different operating points
  - Photo of single measurement rake (left)
  - Operating points: Near Stall (NS), Peak Efficiency (PE) and Near Choke (NC)



[4]

Acknowledgements

- Funding of test facility and rig supported by EFRE
- Fan stage aero design by DLR
- Test rig development mentoring by Rolls-Royce Germany

References

[1] Rolls-Royce plc 2024, *website May 2024*
[2] T. **Eggers**, Zur 3D-Schaufelgestaltung und zum Abströmverhalten des Eintrittsleitrades einer modernen UHBR-Fanstufe. *PhD Thesis 2023*, TU Braunschweig
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[6] L. **Harjes**, Untersuchungen der Strömungsphänomene subsonischer Triebwerkseinläufe bei veränderlichen Längenverhältnissen. *PhD Thesis 2024*, TU Braunschweig

Summary

- Wind tunnel setup with **cross and head wind capabilities**
- Versatile, modular **powered UHBR test rig**
- Experimental investigation of **coupled fan intake interaction** under distorted inflow
- **Adjustable throttle** for various operating points
- Instrumentation for flow analysis plus intake and fan perfomance
- Future uses: BLI test rig, composite rotor blades and fan flutter experiments