Introducing the Fan Rig Darmstadt - Aeromechanics and Aeroacoustics

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Motivation

The improvement of numerical prediction methods for aeromechanics and the understanding of influencing parameters play a key role in the definition of enhanced design rules for modern aero engines. However, new modelling methods entail uncertainties and therefore demand experimental validation, especially in the complex field of fluid-structure-interaction. For this purpose, new fan blade designs, and hence underlying numerical prediction tools, need to be validated through extensive rig testing with respect to their aerodynamic and aeromechanic behaviour to ensure safe and efficient operation.

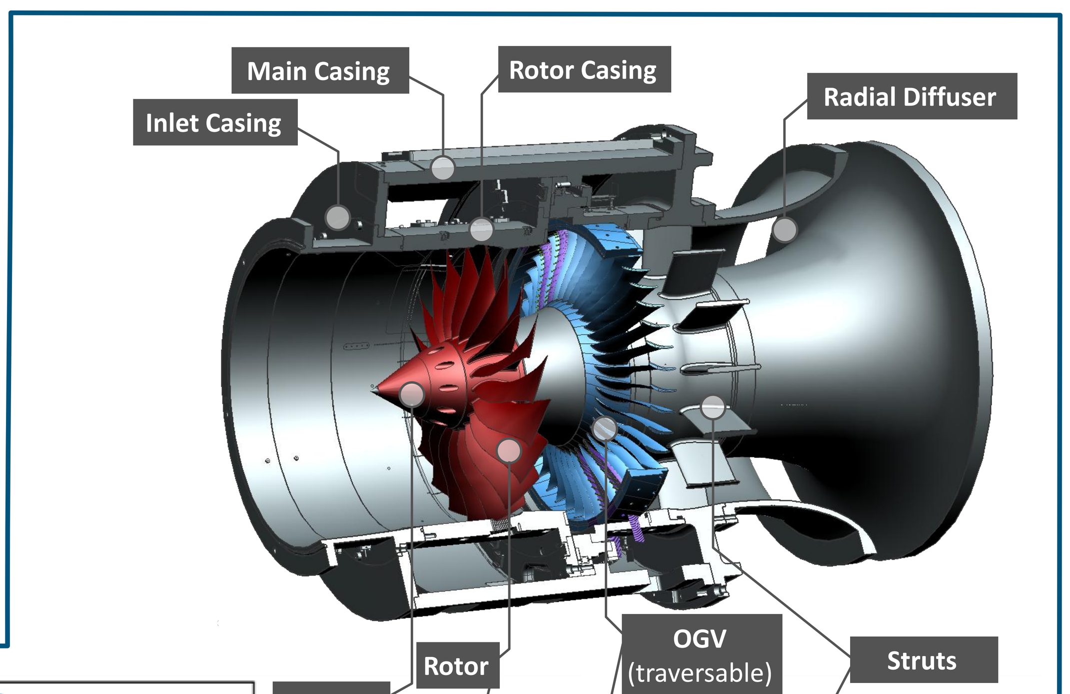
This requirement has resulted in the setup of a new fan test rig, the Fan Rig Darmstadt (FRD), that enables flexible measurement campaigns for comprehensive experimental research on fan aerodynamics and, first and foremost, aeromechanics. For this purpose, the former Transonic Compressor Rig Darmstadt 2 of the Institute of Gas Turbines and Aerospace Propulsion (GLR) at the Technical University of Darmstadt was redesigned to test fan configurations across different engine architectures.

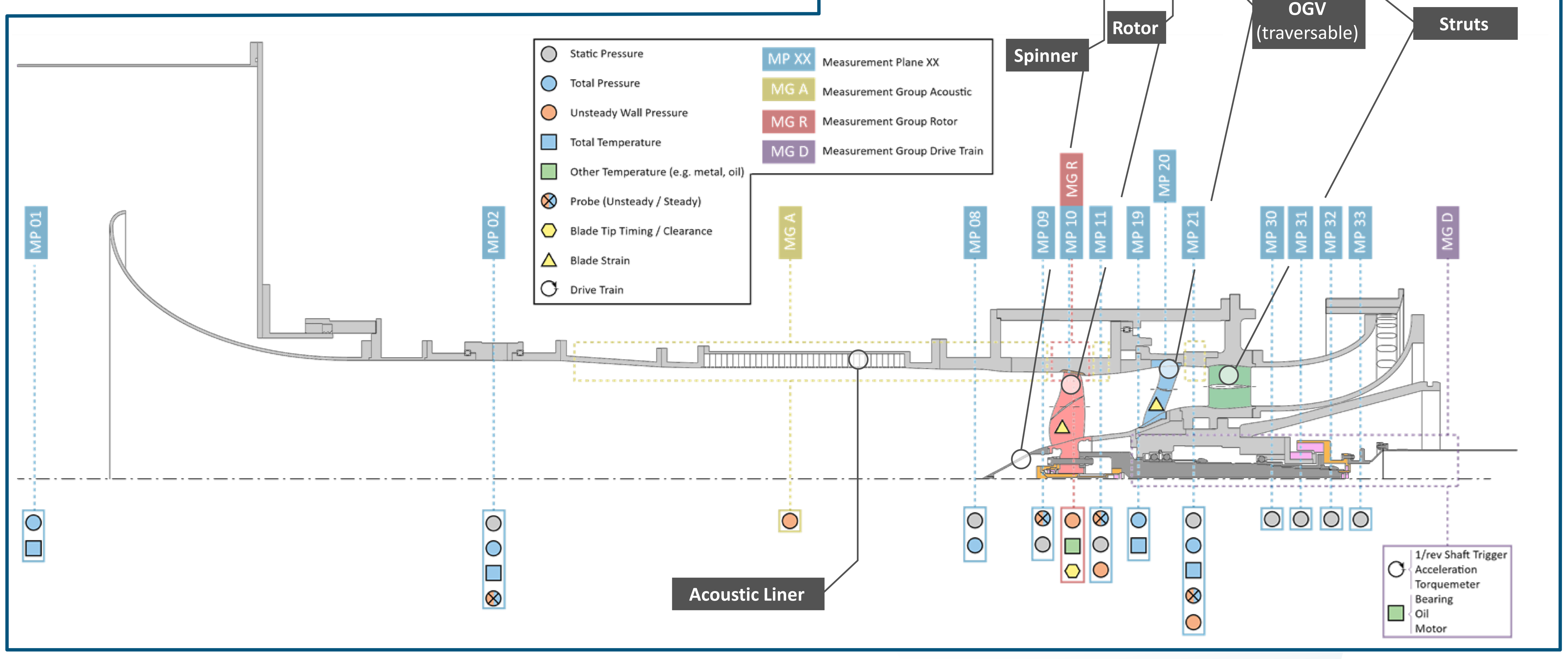
Key Rig Specifications	
Rig type:	Open-loop, ducted, axial
Rotor design type:	Blisk (Titanium)
Rotor diameter:	0.44 m (17.3 in)
Rotor down-scaling factor:	3 … 8
Hub-to-tip ratio @ LE:	0.25 … 0.3
Power:	Max. 1.8 MW
Mechanical speed:	Max. 18,900 rpm
Mass flow rate:	Up to 29 kg/s
Total pressure ratio:	Up to 1.7
Rotor-relative tip Mach number:	Up to 1.4 → transonic

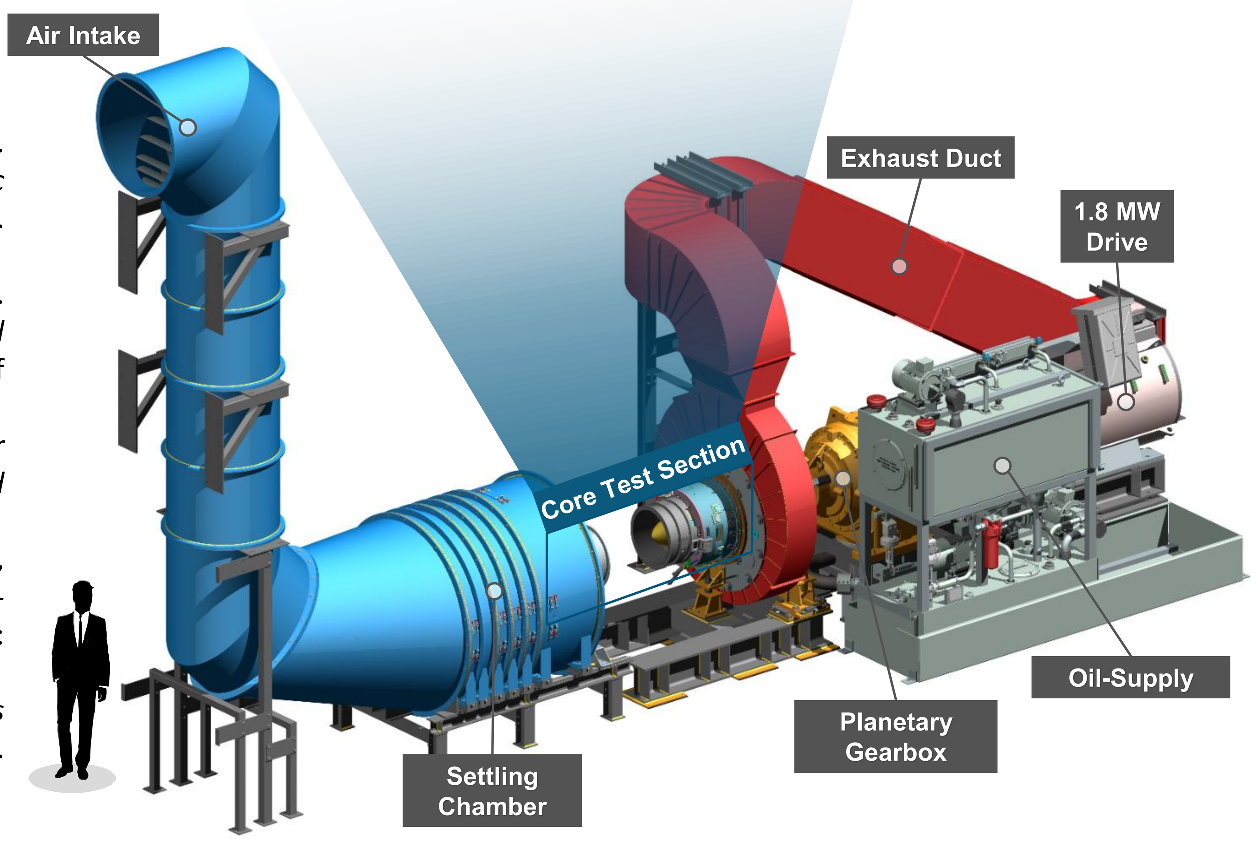
Main Objectives of the Rig

1. Enable **extensive and flexible experimental investigations** on the aerodynamic and structural dynamic behaviour of **varying fan stage configurations**
2. Enhance the **root cause understanding of aeroelastic and aeroacoustic phenomena**, initially focusing on fan blade flutter
3. Enable the **systematic validation of new aeromechanics prediction methods** through back-to-back comparison of different fan blade design variants

Key Rig Features	
Modularity	Fast-swap of components (inlet duct, blisk, rotor casing, OGV)
Mapping of the Operating Range	Part-speed to overspeed, variable throttle along speed line from choke to stability limit & beyond
Stability Mapping	Aerodynamic & structural, comprehensive H&S monitoring & emergency bleed system
Data Synchronisation	Time synchronisation of all measurement systems via OPR trigger attenuation
Extensive Instrumentation	Steady (100 Hz) & unsteady (1.3 MHz)







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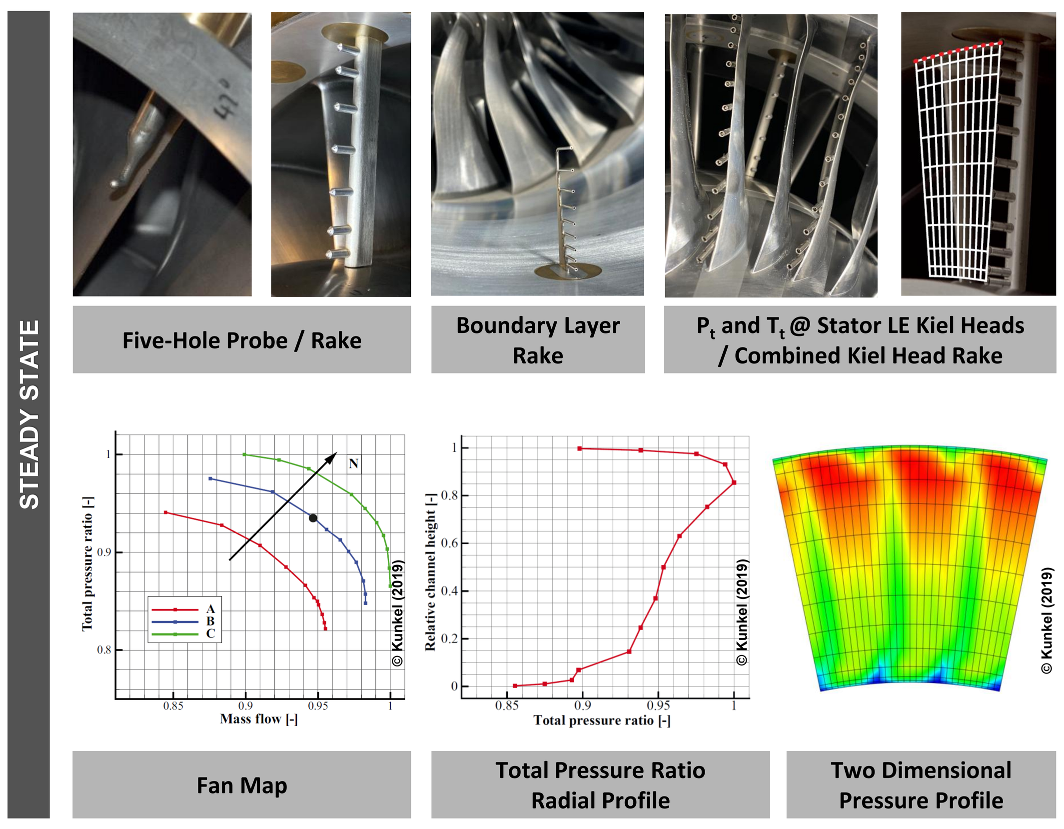
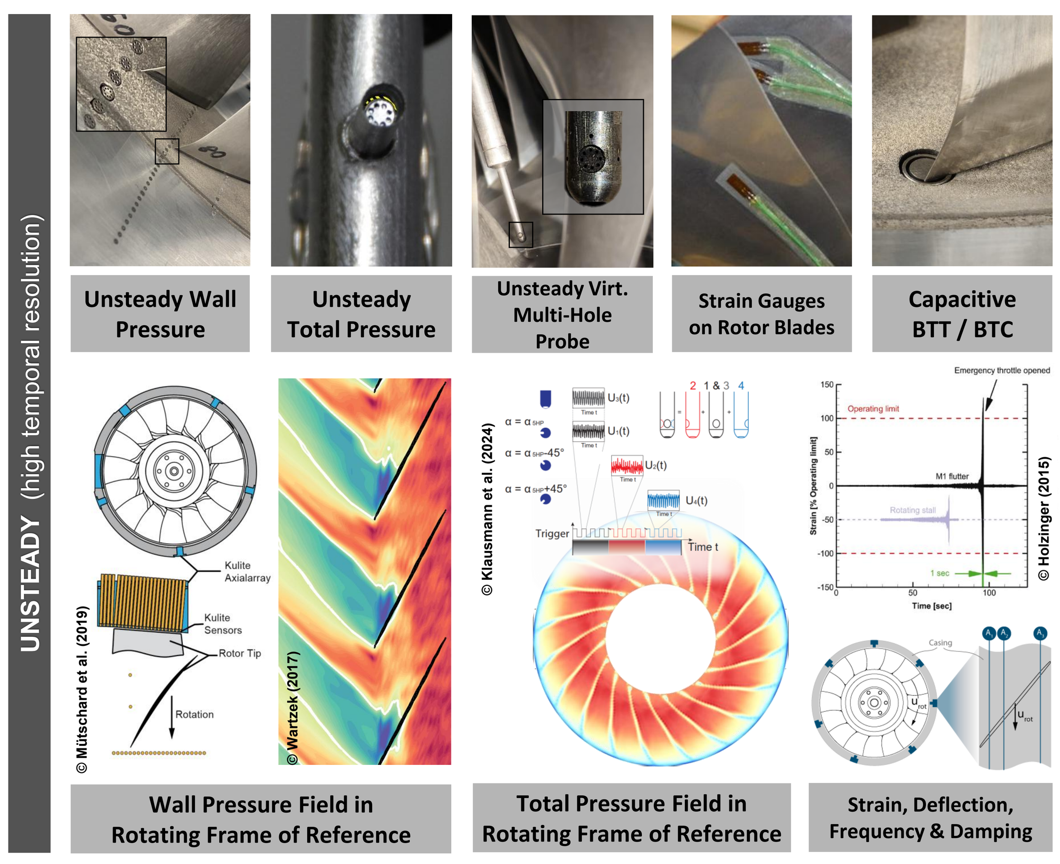
Instrumentation

High-quality time-resolved and synchronised experimental data is essential to enhance the understanding of aeroelastic interaction mechanisms in modern UHBR fan configurations and to enable the validation of corresponding prediction methods.

The test rig features state of the art steady-state aerodynamic and performance instrumentation, allowing the determination of fan maps as well as detailed flow parameters such as radial profiles and 2D flow fields using traversable probes, rakes as well as flush-mounted pressure ports.



Furthermore, it comprises extensive unsteady instrumentation for acquisition of transient aerodynamic, acoustic and structural effects as well as their interaction. For this purpose, the rig is equipped with over 80 unsteady wall pressure transducers distributed axially and circumferentially over the rig, predominantly in the rotor region. Virtual multi-hole-probes are used to determine the flow parameters in the rotor-relative frame of reference.



Blade vibrations are monitored and recorded via strain gauges on the rotor blades in combination with a telemetry-system. A capacitive blade tip clearance and blade tip timing system (BTC/BTT) is additionally used to measure deflection amplitudes, nodal diameters and running tip clearances.

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