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# Performance and Stability Analysis of a Highly-Loaded Low-Pressure Compressor Under Distorted Inflow Conditions


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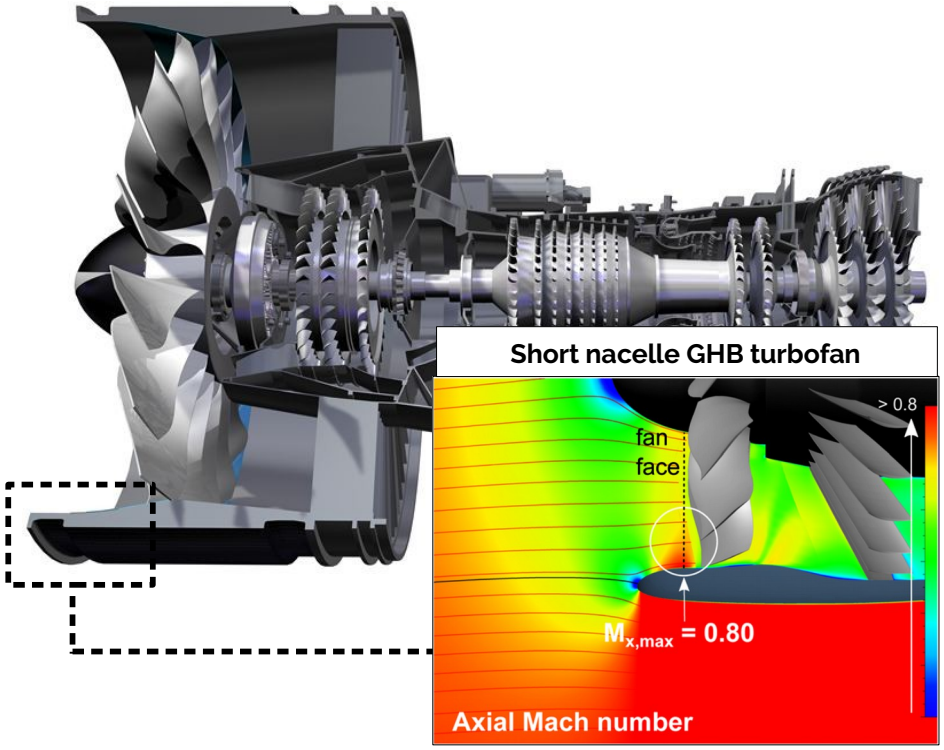
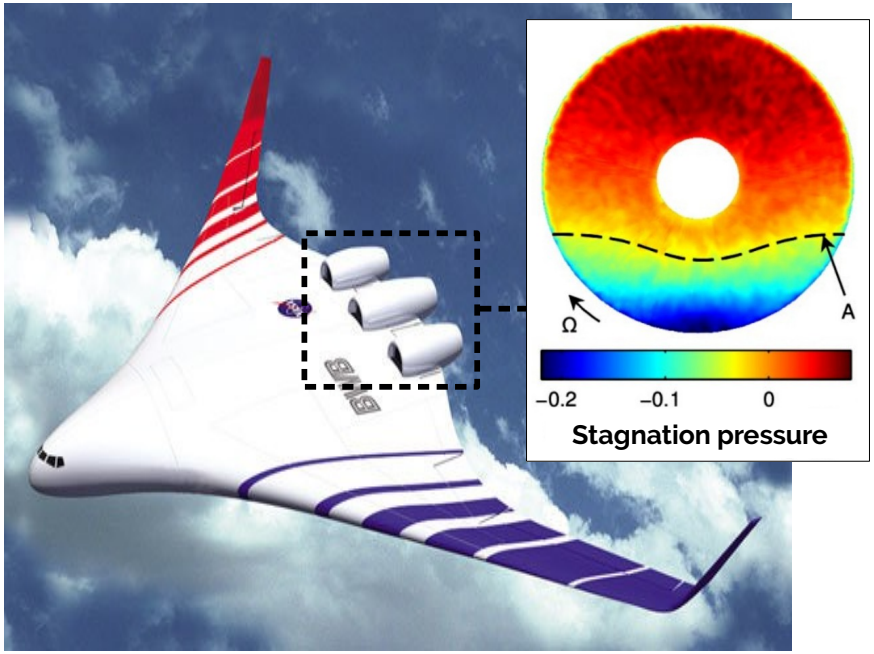
# Context

The environmental legislation and the growth of the aviation sector are requiring the development of modern aircraft systems to reduce $CO_2$ and $NO_x$ emissions

## Geared high-bypass turbofans




## Boundary layer ingestion




✔ Improvement of the efficiency

✗ **Generation of inlet distortions**

Credit: https://aerospaceamerica.aiaa.org/features/high-gear/

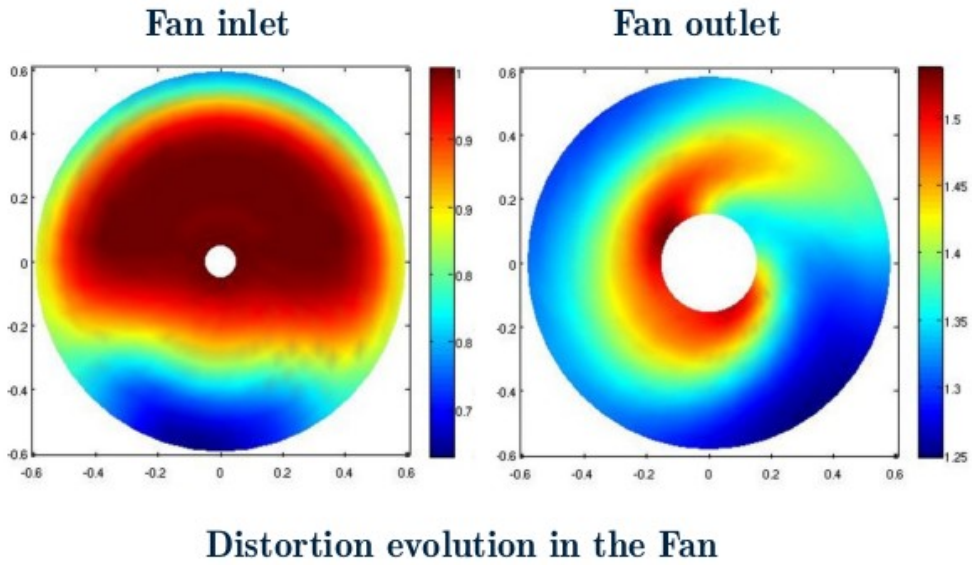
Peters A. et al. "Ultrashort Nacelles for Low Fan Pressure Ratio Propulsors" Journal of Turbomachinery 2014

Leiffson L.T. *"Multidisciplinary Design Optimization of Low-Noise Transport Aircraft"* PhD thesis, Virginia Polytechnic and State University, 2005

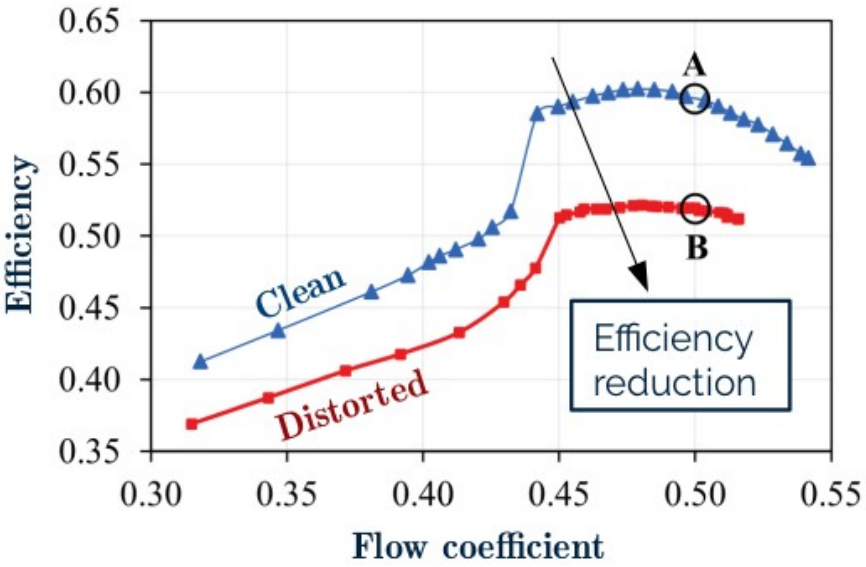
Gunn et al. "Aerodynamics of Boundary Layer Ingesting Fans" ASME Turbo Expo 2014

# State of the art

Given its crucial role in the overall propulsive efficiency, the fan has been the only focus of research on distortion effects




Distortion evolution in the Fan




**However:**

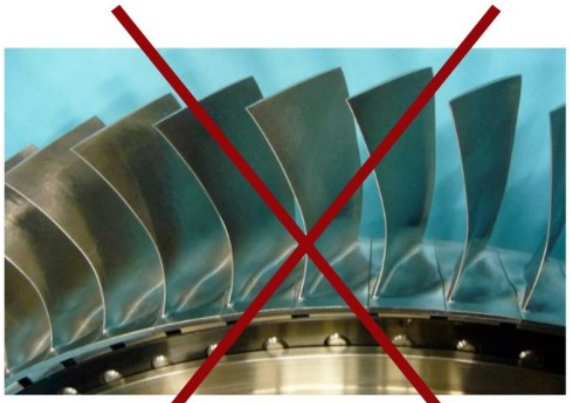
- Only in the last years the low-pressure compressor (LPC) is having a crucial role in the delivering of the overall pressure ratio
- The aerodynamic and structural design differences do not allow for a direct extension of results to the LPC

Plas A.P. et al. "Performance of a Boundary Layer Ingesting (BLI) Propulsion System" 45 th AIAA Aerospace Sciences Meeting and Exhibit 2007
Gunn E.J. et al. "An Experimental Study of Loss Sources in a Fan Operating With Continuous Inlet Stagnation Pressure Distortion" Journal of Turbomachinery 2013

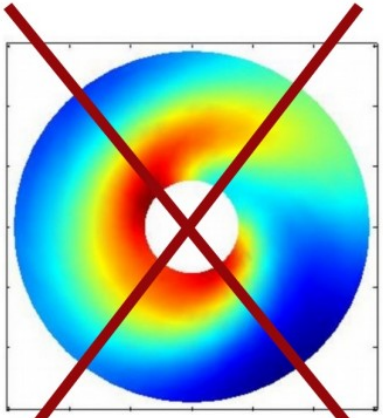
# Motivation and objective

## Motivation

No representative geometries and distortions for the LPC are currently available



Modern blade shape



Real distortion patterns

## Research objective

**Assessment of the global performance reduction and the dynamic behavior of modern LPC under "real" distortions**

How? **Description of the involved flow physics!**

Plas A.P. et al. "Performance of a Boundary Layer Ingesting (BLI) Propulsion System" 45 th AIAA Aerospace Sciences Meeting and Exhibit 2007

# Research activity

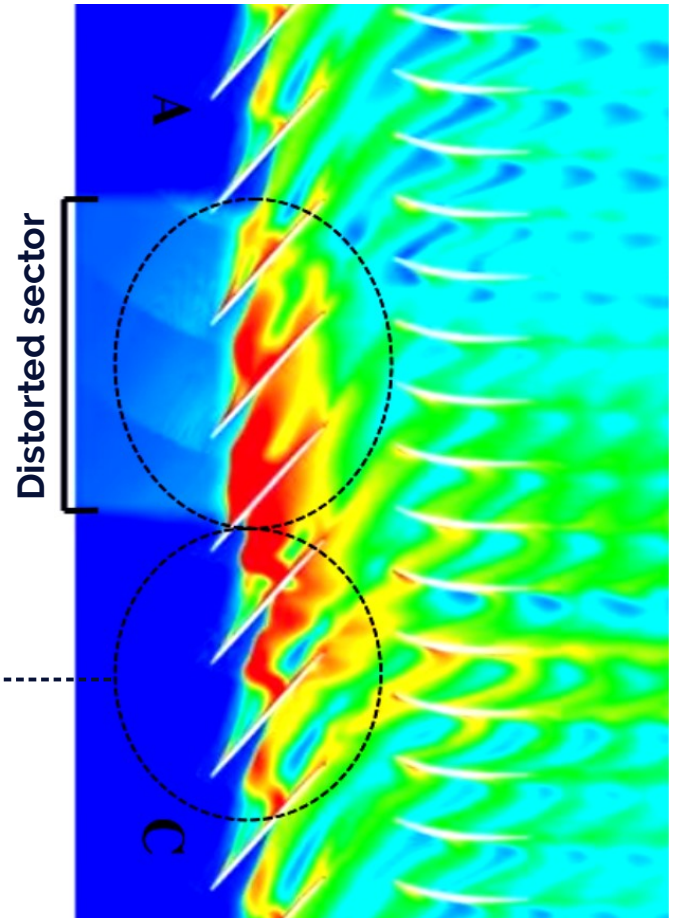
## **Step 1** Bibliographic research

- Define in detail the research methodology
- Identify the most critical distortions for the LPC

## **Step 2** Numerical simulations

- Critical distortions used as inlet BC
- Design of experiments:

  - Increased spatial and temporal resolution in secondary flows and gradient regions
  - Right bandwidth for the instrumentation
  - Probes location optimization

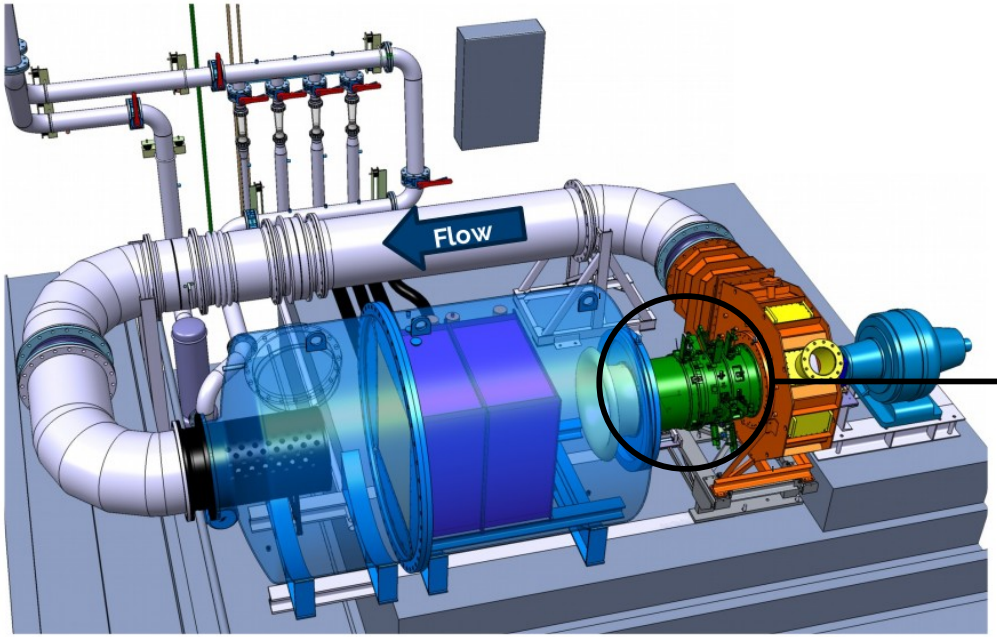


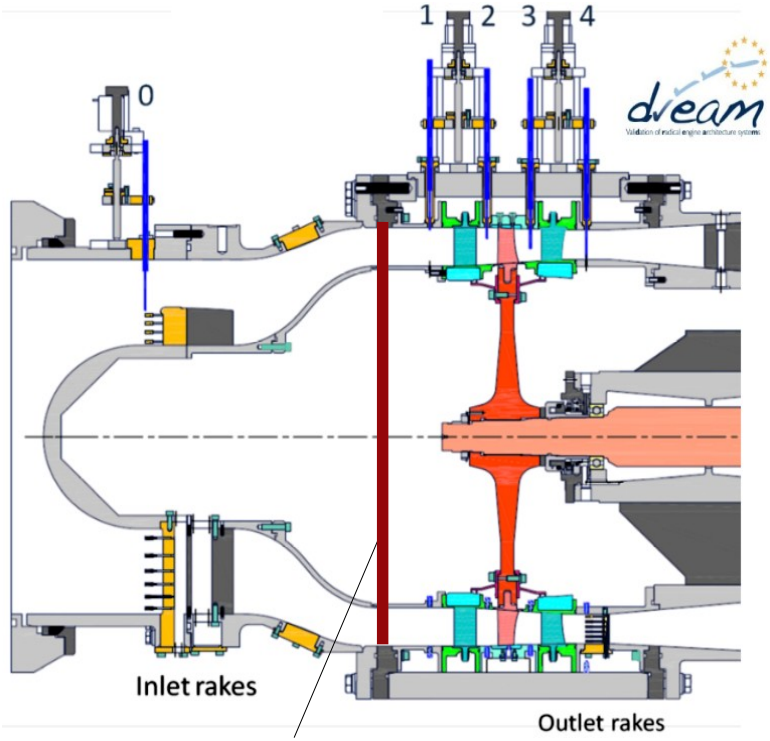

Lesser A., Niehuis R. "Transonic Axial Compressors With Total Pressure Inlet Flow Field Distortions" ASME Turbo Expo 2014

# Research activity

## **Step 3** Experimental campaign

- Steady and unsteady measurements in engine like conditions (VKI-R4 facility) and representative geared LPC (DREAM stage)




**Distortion screen** (Astoria)

## **Step 4** Physical interpretation

- Flow phenomena linked to performance and stability reduction
- Stall inception mechanisms and post-stall behavior
- Design guidelines for the next generation of LPC

# Preliminary results

## 1. Bibliographic survey

- Distortion characterization (Distortion Indices)
- Parallel compressor model
- 3D flow topology in compressors under distortion
- Numerical  feasibility

## 2. Numerical simulation

- Preliminary steady computations of DREAM in clean conditions