Hybrid Parallelization of the CFD Code PANTA

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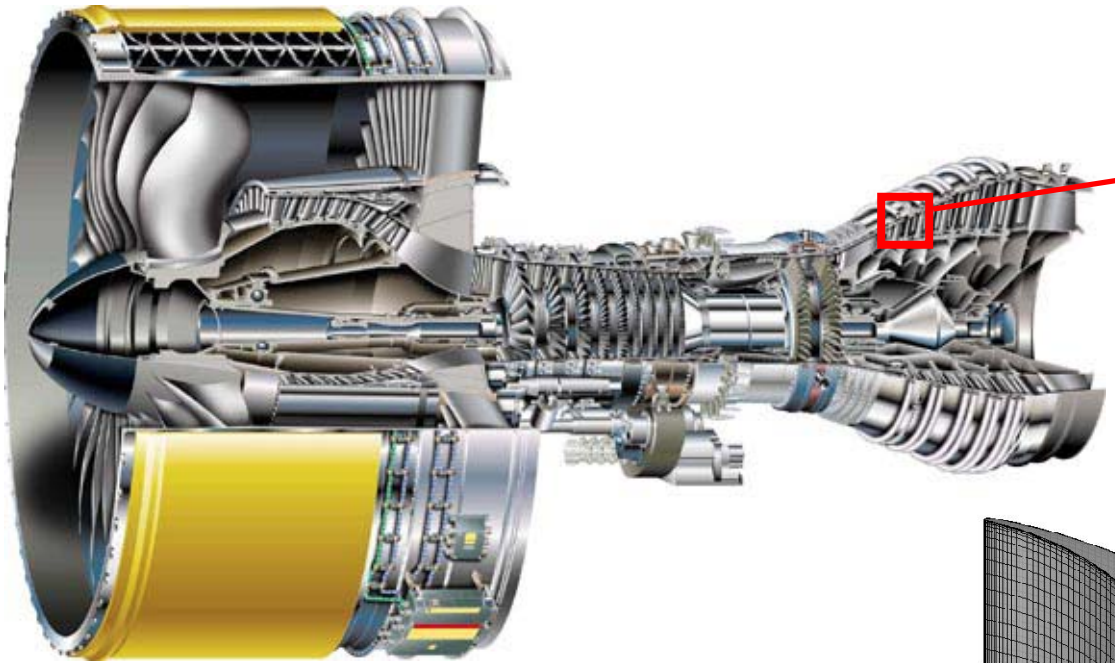
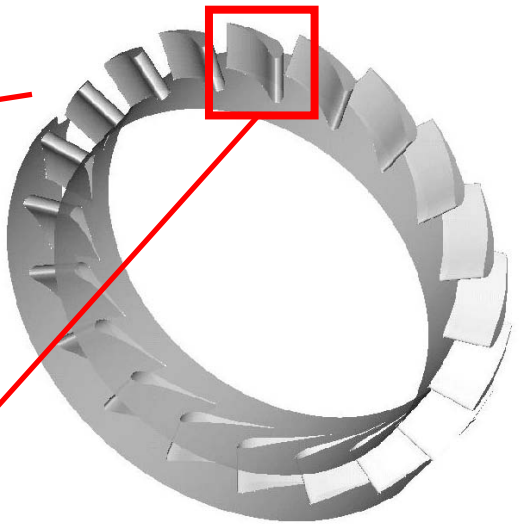
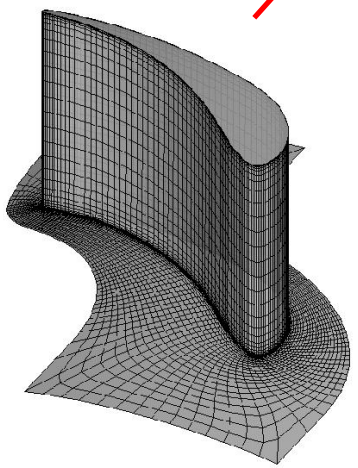
CFD Code ***PANTA*** - Computation of Turbomachinery Flows



GP7200 Jet Engine
for Airbus A380

Low Pressure Turbine
Blade Row

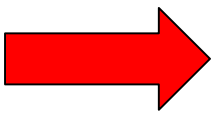




Low Pressure Turbine
Blade Channel

CFD Code ***PANTA*** - Flow Solver

- Cell-Centered Finite Volume Method
- Implicit Time Integration
- Reynolds- and Favre-averaged Navier-Stokes Equations
- k-ε Turbulence Model



System of 7 Coupled Partial Differential Equations

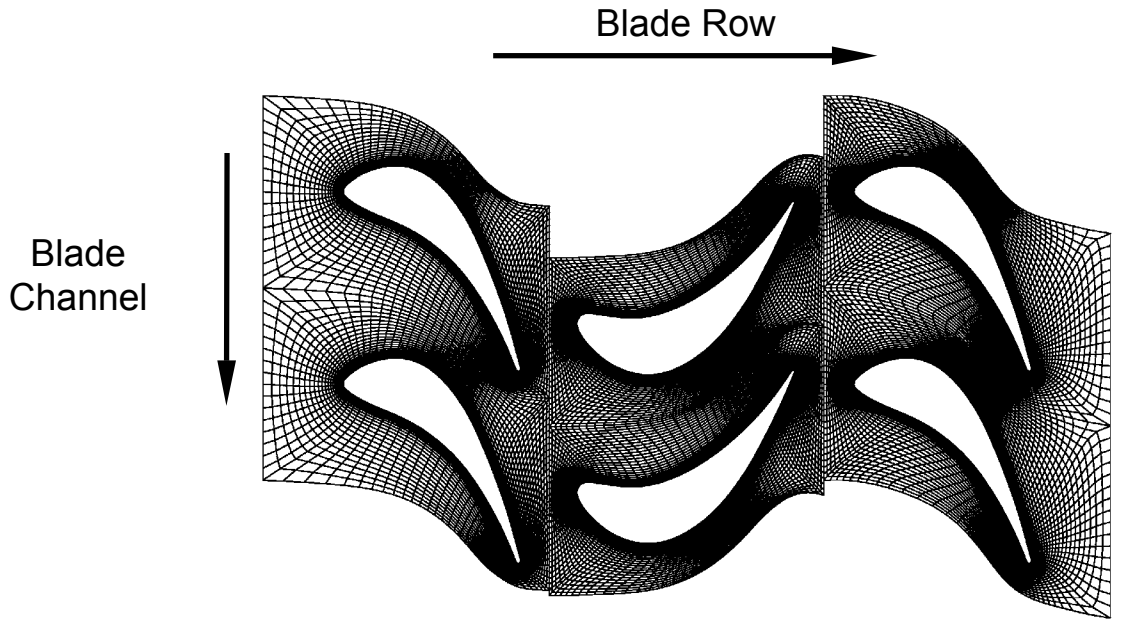
CFD Code ***PANTA*** - Program Structure

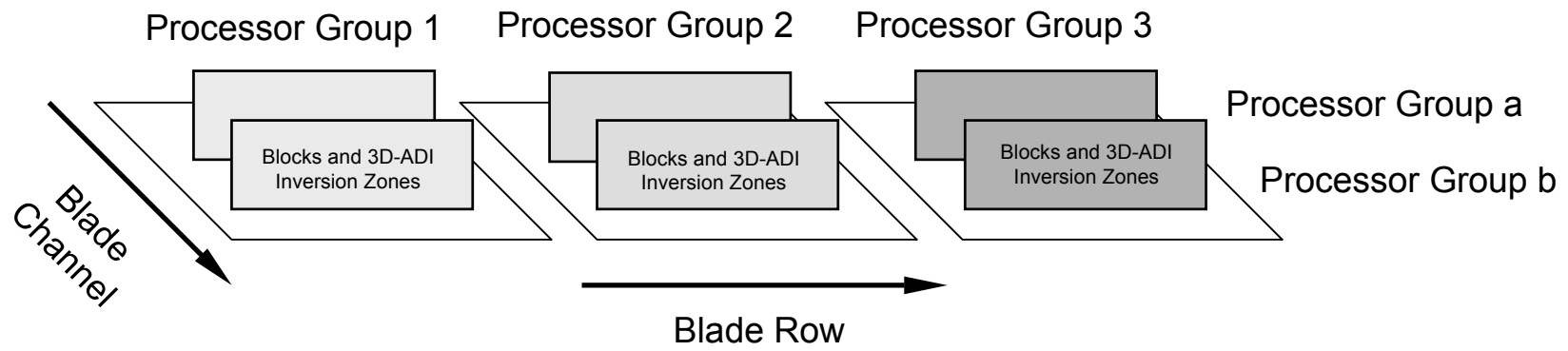
- Preparation, input

- Computation
- S loop over footsteps (~1000-5000)
- S loop over linearized Newton steps (1-4)
- P loop over blade rows (1-7)
- P loop over blade channels (1-7)
- P loop over geom. blocks (1-20)
- P loop over zones (1-80)
- S iteration loop (8-14)
- P lin. equ. solver

- Postprocessing, output

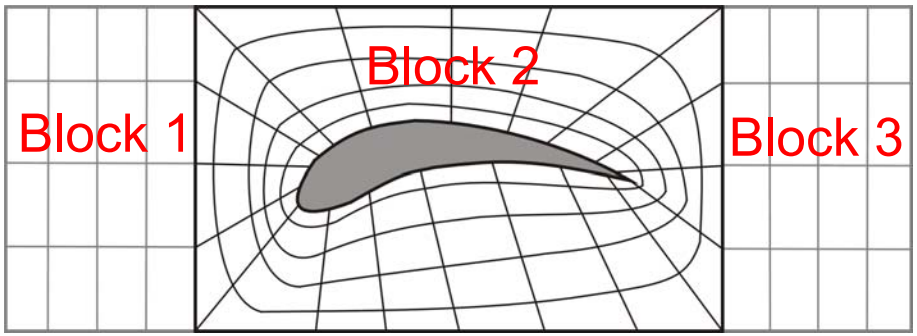
CFD Code ***PANTA*** - Loops over Blade Rows and Channels



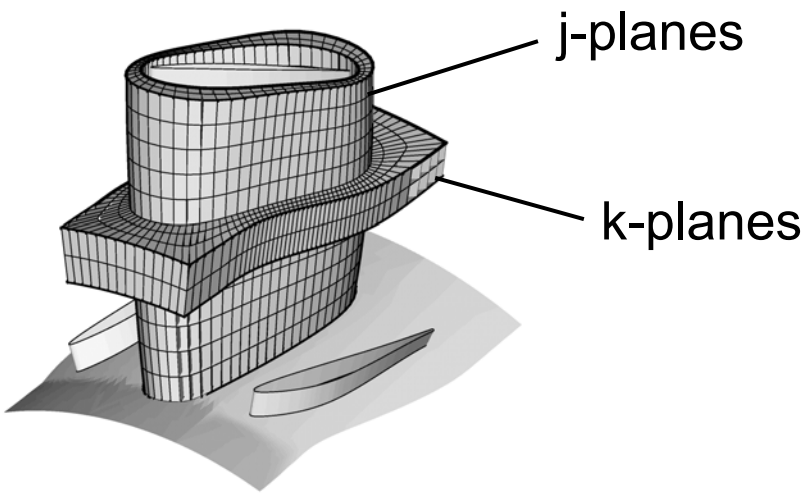


CFD Code ***PANTA*** - Loops over Blocks and Inversion Zones

Blocks



Alternating Direction Inversion Zones



CFD Code ***PANTA*** - Nested/Hybrid Parallel Version

- Current Status: Nested Parallelism with MPI
- Ideas for OMP*lab:*
  - Analysis and Tuning of OMP Parallelized Loops
  - Analysis and Tuning of Hybrid Version (OMP+MPI)
  - Analysis and Tuning of OMP Nested Version

- S (MPI/OMP) loop over blade rows (1-7)
- **MPI** (OMP) **loop over blade channels (1-7)**
- S (MPI/OMP) loop over geom. blocks (1-20)
- **MPI** /OMP **loop over zones (1-80)**
- S iteration loop (8-14)
- V/OMP **lin. equ. solver**

CFD Code ***PANTA*** – Nested OpenMP Parallelization

- First prepare both OpenMP levels separately
- Assure / ThreadChecker and Sun Analyzer essential tools in the developement cycle
- Bugs found in Assure, ThreadChecker, Intel Compiler, Sun Studio8 Compiler

Runtime (seconds) / # Threads	1	2	4	remarks
OpenMP on loop level (lin. equ. solver)	89	64	51	68 OpenMP directives (so far)
OpenMP coarse-grained (loop over zones)	99	54	35	55 out of 132 common blocks now threadprivate 8 hours / 2GB per Assure run with minimal dataset

- **Default(threadprivate)** in combination with detection of uninitialized variables might be helpful and safer!