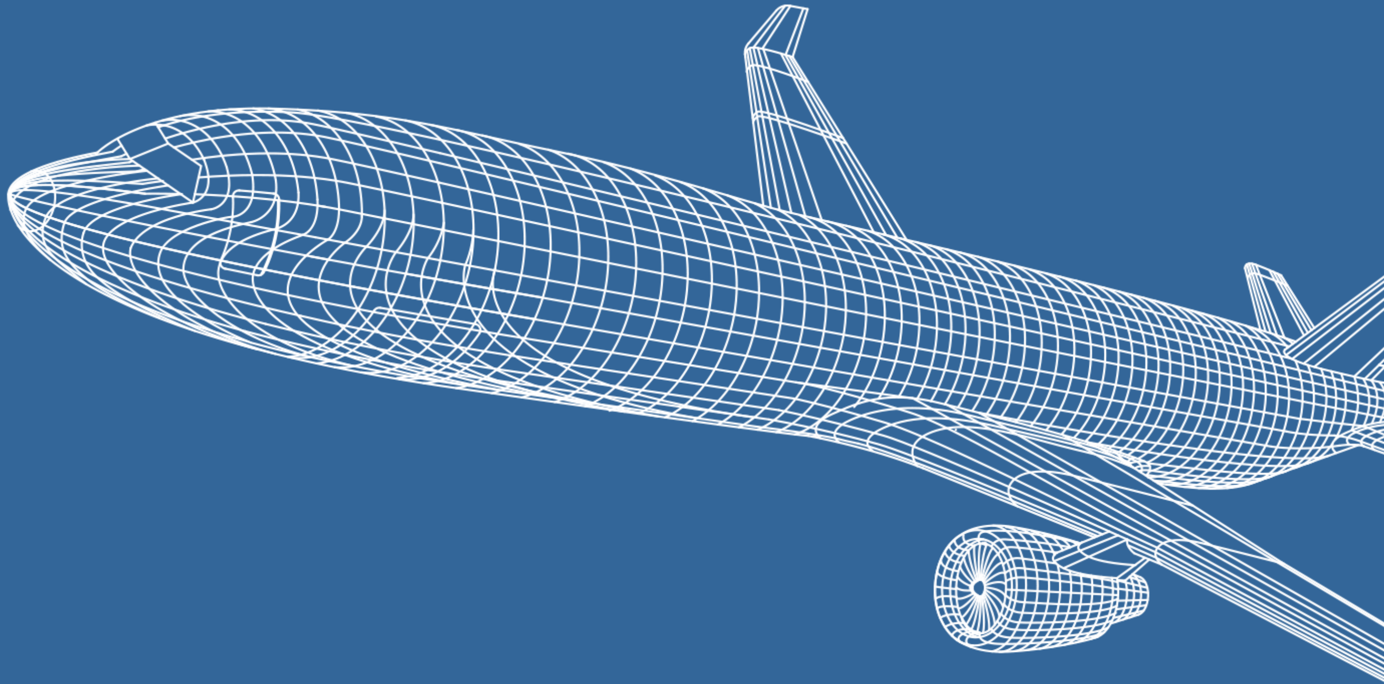

Multidisciplinary Optimization for Integrated Design of Aero-engine Components

Design for Performance

Visakha Raja | 11 October 2016

Agenda

- Introduction
- Project Context
- GKN Structures (or components)
- System and component level analyses
- Structures optimisation
- Conclusion

Project Context

- Project titled Design for Performance (DFP)
- Cooperation among
  - GKN Aerospace Sweden AB
  - Chalmers Product and Production Development
  - Chalmers Applied Mechanics
- Funding : Vinnova - NFFP6

  http://www.vinnova.se/sv/Resultat/Projekt/Effekta/Konstruktion-for-Prestanda---avancerad-motorarkitektur-och-integration/
- Industrial PhD, part of DFP
- Primary concern: GKN's engine structures

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People Involved

Prof. Ola Isaksson Prof. Em. Hans Johannesson Visakha Raja Prof. Michael Kokkolaras	Chalmers University of Technology Department of Product and Production Development
Prof. Tomas Grönstedt Sebastian Samuelsson Olivier Petit Xin Zhao Anders Lundbladh	Chalmers University of Technology Department of Applied Mechanics
Anders Lundbladh Visakha Raja	GKN Aerospace Sweden AB
Prof. Michael Kokkolaras	Department of Mechanical Engineering McGill University, Montreal, Canada.

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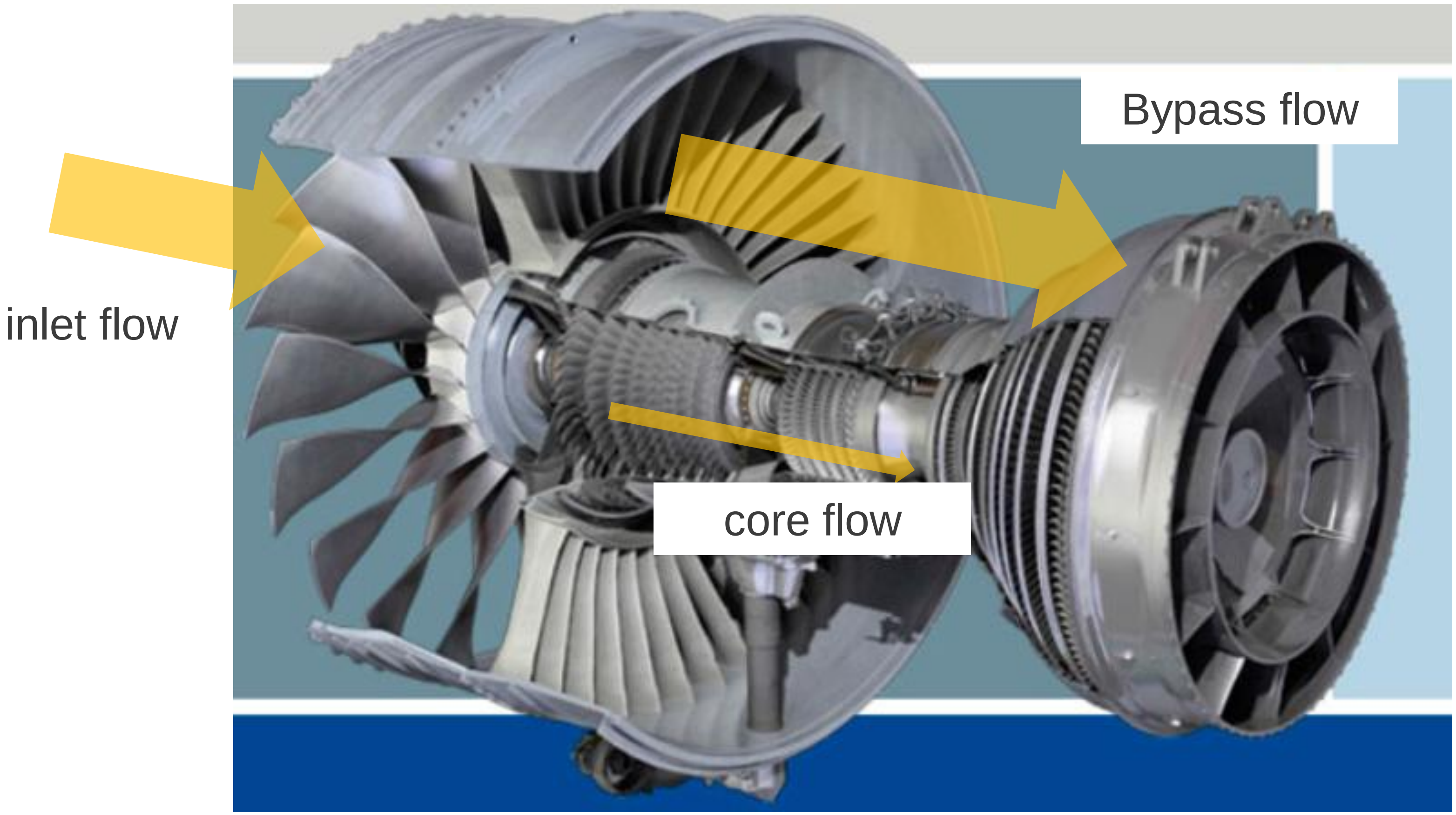
The Turbofan Engine



GKN's Engine Structures

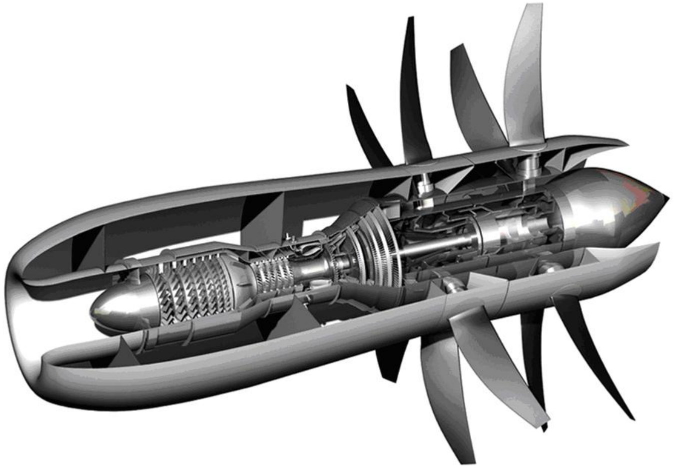
- **Hot structures**
  - Located after combustor, hot section; Mainly turbine structures
- **Cold structures**
  - Located before combustor, cold section; Compressor fan structures

Figures of structures are only representative and do not correspond to that in the engine shown.

Turbofan Developments

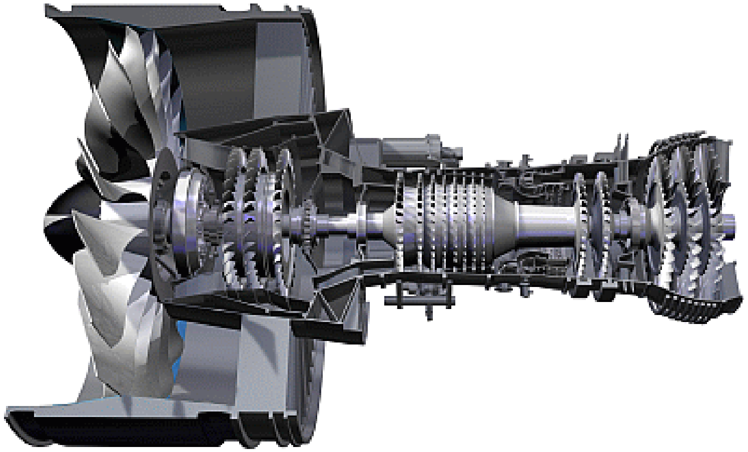
LEAP

https://www.cfmaeroengines.com/engines/leap/



Open Rotor

http://ec.europa.eu/research/transport/news/items/dream_ip_encouraging_results_en.htm

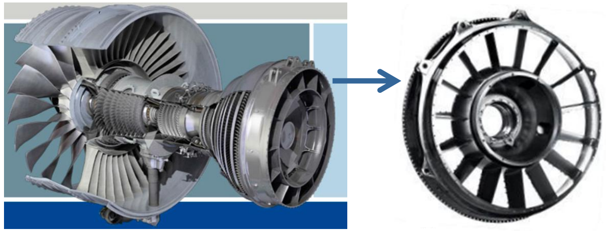


PW1000 G

http://www.a320neo.com/airbus-a320-neo-photo-album/pratt-whitney-pw1000g-purepower-engine-cross-section.php

Need to be proactive about system developments

System and Component Level Analyses



- Turbine Rear Structures (TRSs
- Multidisciplinary design tasks
- System interaction with component (engine -> TRS)
  - BCs *from* system *to* component
- Analyses differ from component to system level
- System component interaction measures will enable:
  - Better tuning of component designs to system operations

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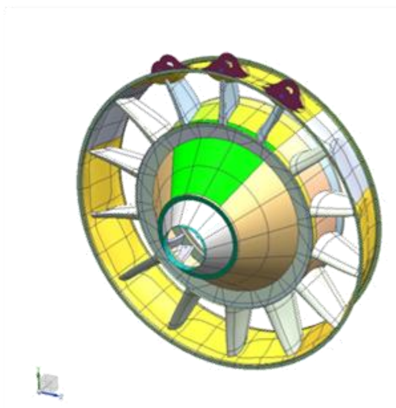
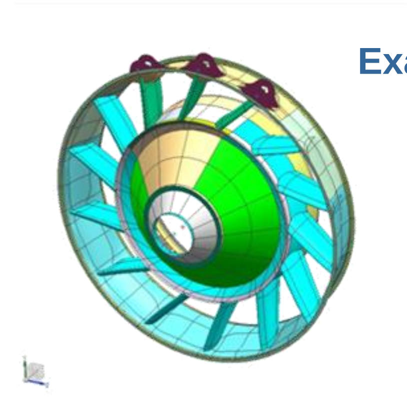
Alternative Designs

- Trading becomes necessary among design parameters



Example



Example

Aerodynamically Good Design wrt Pressure Drop : Can be poor from Weight or Lifing perspective	Aerodynamically Poor Design wrt Pressure Drop: Can be good from Weight or Lifing perspective

- Pressure drop, just one performance impacting factor

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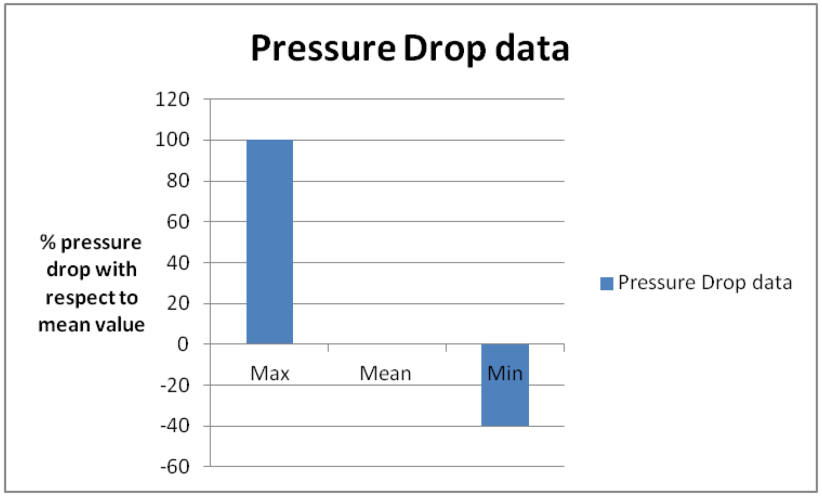
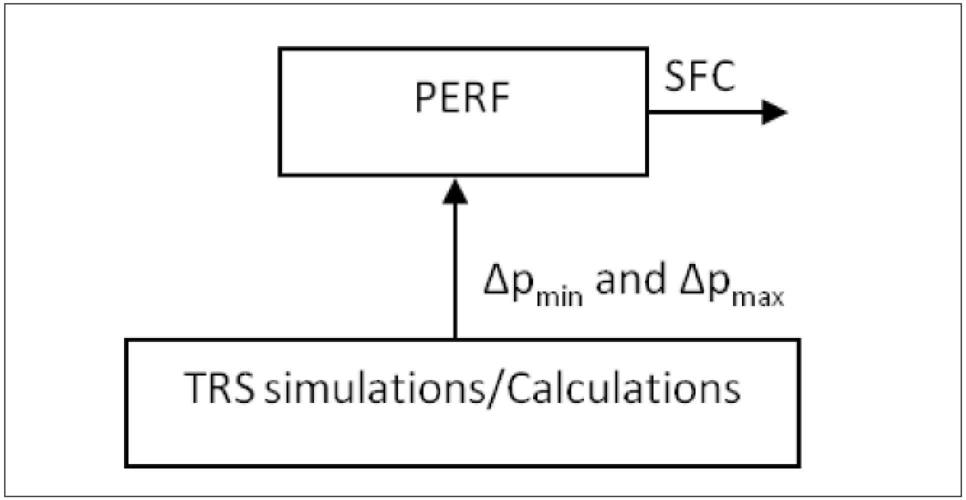
A System Component Coupling Approach

- Couple pressure drop with system SFC calculation
- Pressure drop ranges for aerodynamically well designed TRS
- Single pressure drop value for poorly functioning TRS





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Components' Effects on System

- 0. 9% difference in SFC
  - Aerodynamically well designed vs Aerodynamically poorly designed
- System (engine) level effects cannot be neglected
- More valid results if more levels are included

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The Lower Level Structure Design Problem

- Given LPT for a certain engine:
  - Perform preliminary assessments on the rear structure (TRS)
  - Stiffest and lightest TRS
  - In this presentation, only one way coupling is considered

Low Pressure Turbine simulations

Allowable tip and hub radial positions

Weight

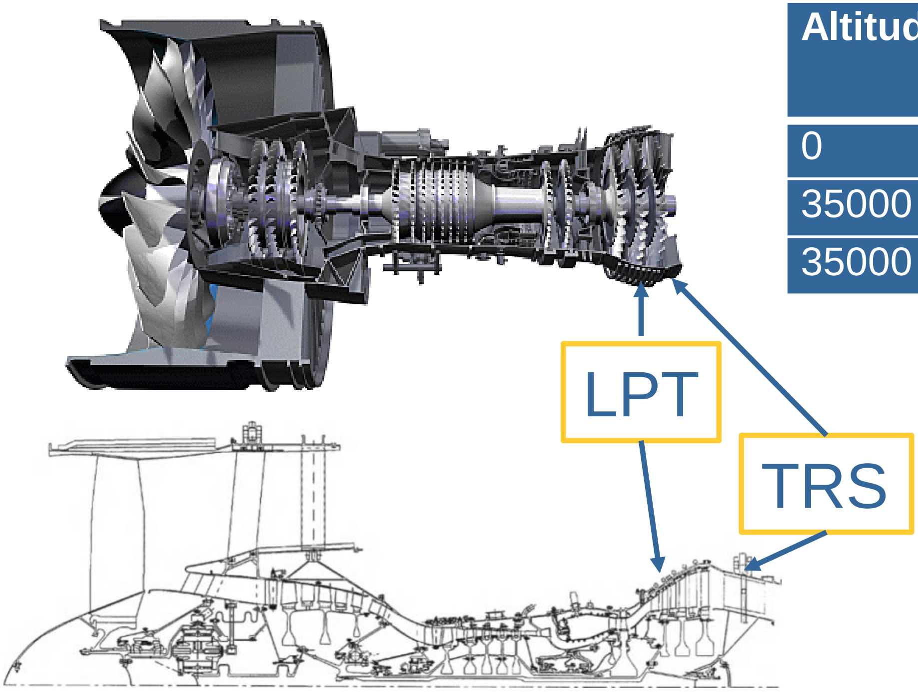
Core flow pressure drop in the component

Interface positions

Boundary conditions for flow through TRS

TRS structural simulations

Engine Design Details



Geared turbofan example:
Pratt&Whitney PW1000G GTF
Source: http://www.a320neo.com/airbus-a320-neo-photo-album/pratt-whitney-pw1000g-purepower-engine-cross-section.php

Altitude (ft)	Mach	ΔISA (°K)	Rating	Thrust (kN)
0	0.25	15	Take-off	252.1
35000	0.82	10	Top of Climb	67.3
35000	0.82	0	Cruise	51.2

Operating points and thrust requirements

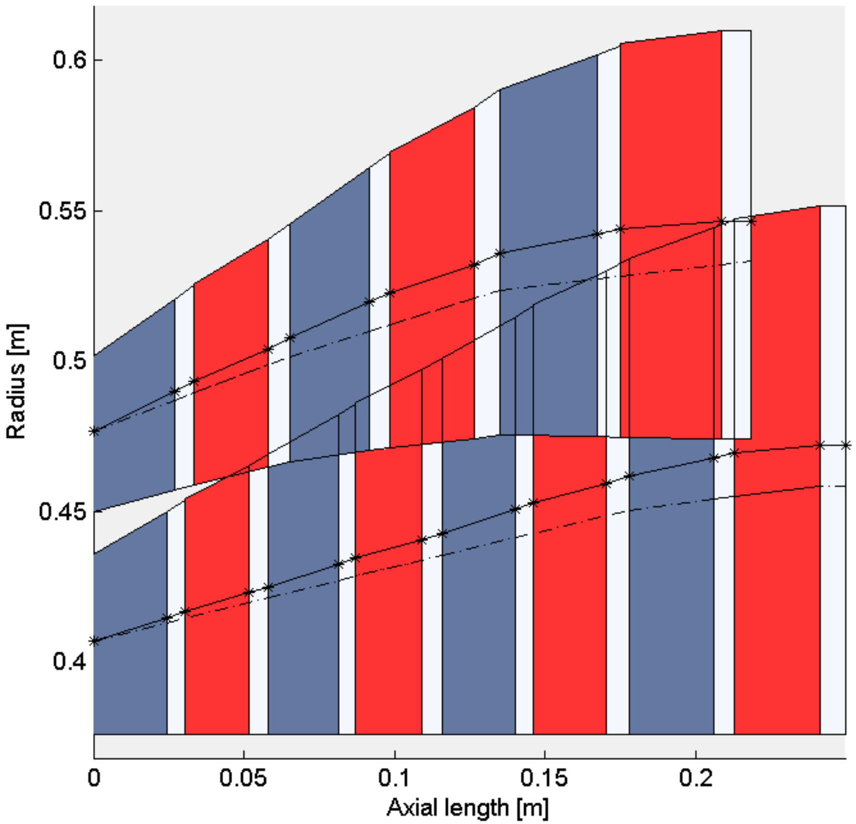
Geared turbofan	Top of climb
OPR	55.7
BPR	12.4
Fan PR	1.29
IPC PR	2.48
HPC PR	17.37
Gear box ratio	3.115
Turbine inlet temperature (K)	1838
LPT rotational speed (RPM)	6237

Engine performance data

LPT Design Details

	Inlet Properties
Inlet mass flow	42.615 kg/s
Inlet T total	1290 K
Inlet P total	5.11 bar
Power requirement	23.28 MJ/s
Inlet cooling mass flow (%)	0
Inlet flow angle	0

LPT design inlet properties



3-stage LPT considered in this case

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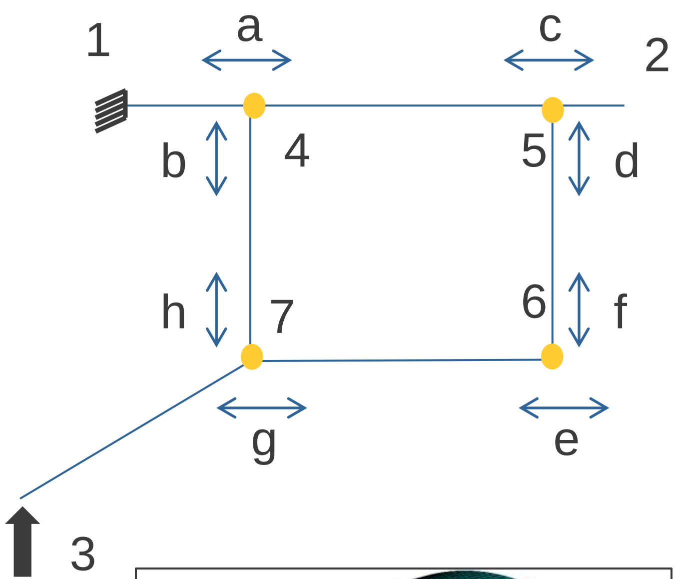
CHALMERS

The TRS Stiffest Structure Problem



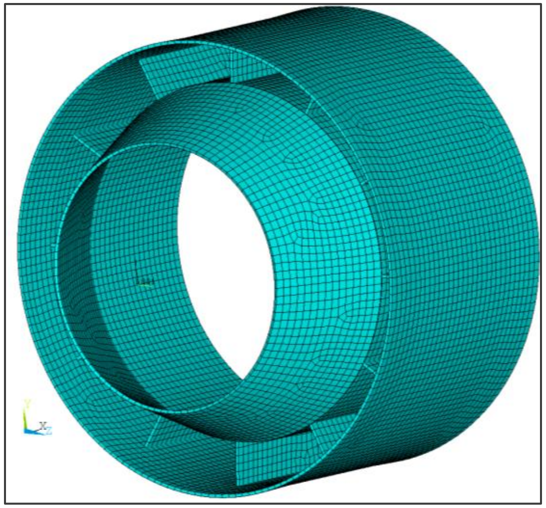
Problem specification:

Say, G = [a b c d e f g h], the geometrical variables

min. G **Stiffness**

s.t **G_lower ≤ G ≤ G_upper**

Stiffnes = Load at point3/displacement at point 3



G_upper: upper limit on the movements allowable for the points 4, 5, 6 and 7

G_lower : lower limit on the movements allowable for the points 4, 5, 6 and 7

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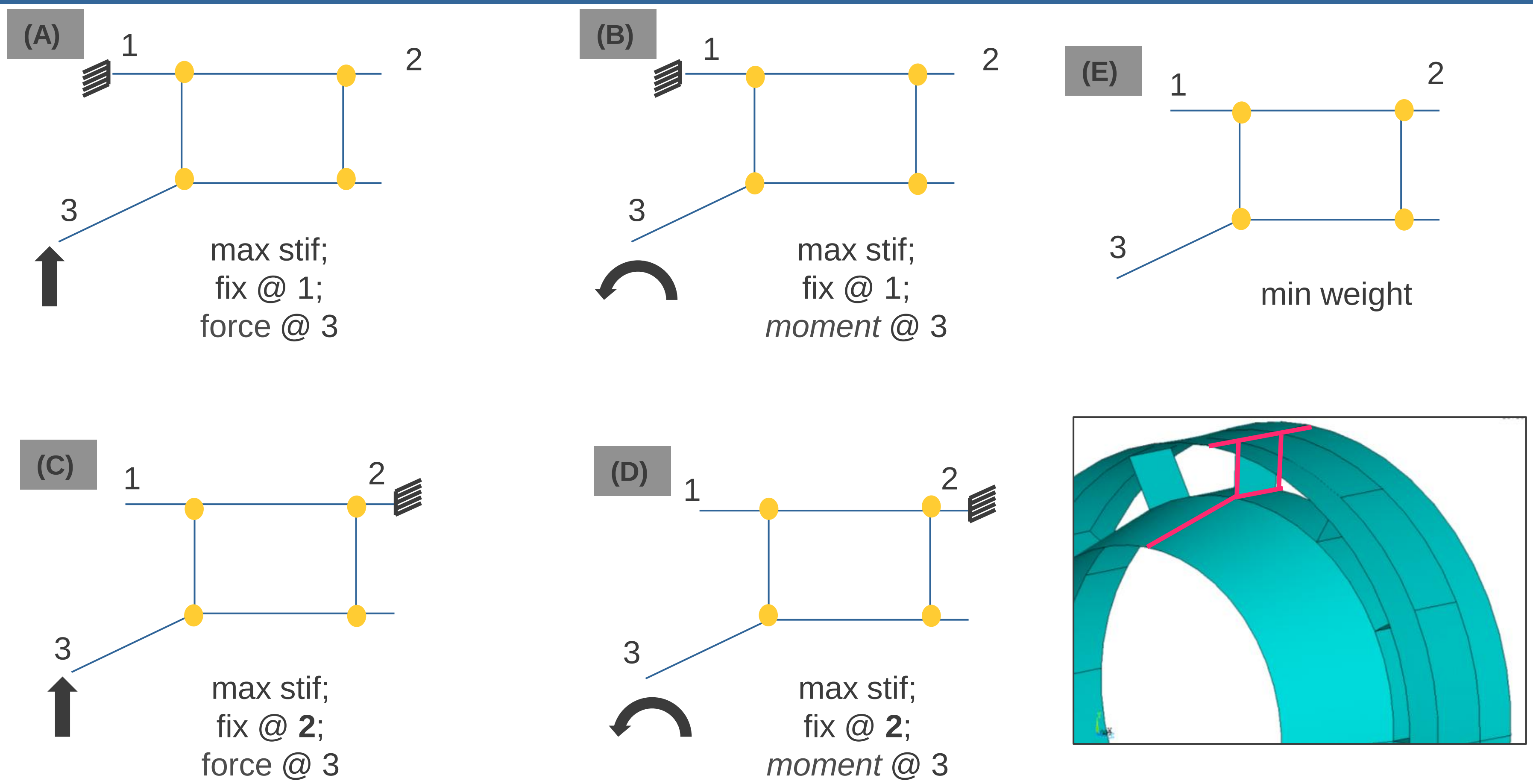
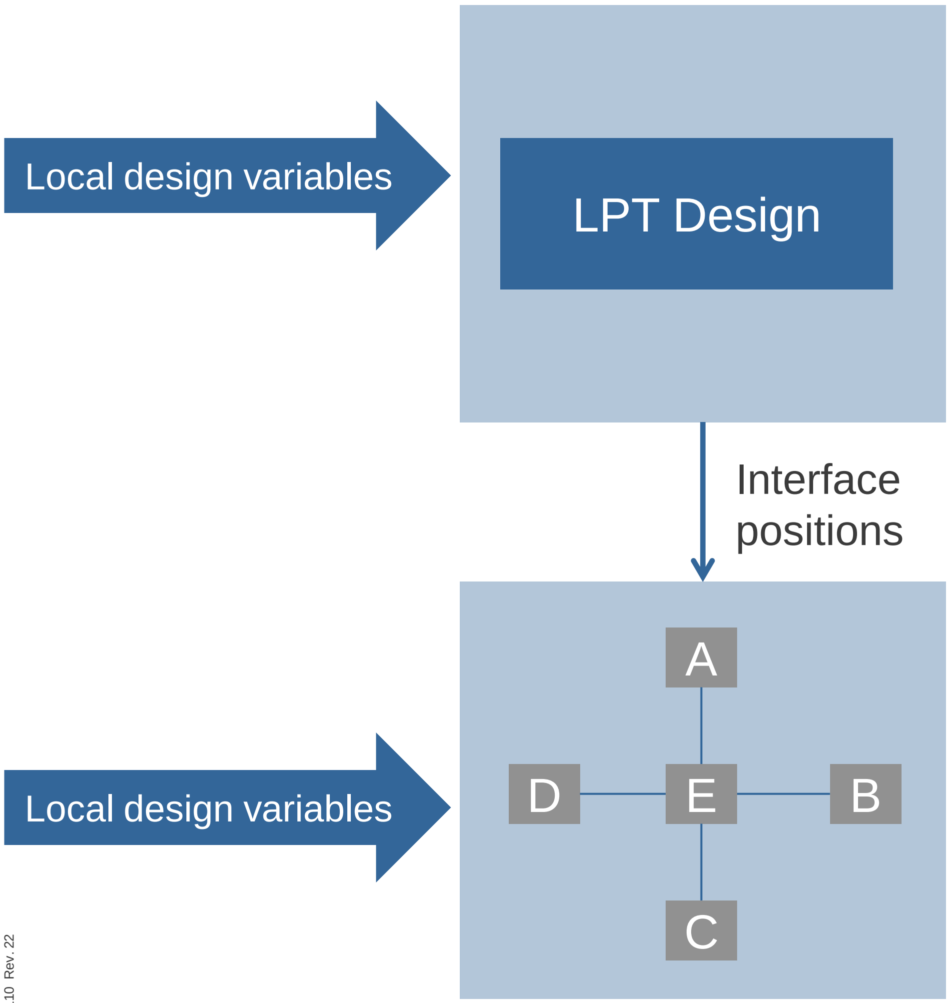
Optimise Load Path Across Load Cases



Find the *stiffest & lightest TRS geometry* for a certain turbine *by varying the geometrical position* of TRS vanes

Problem Co-ordination



LPT design

(Chalmers Applied Mechanics)

Multiple
disciplines/levles/instituitions !

Structures Design

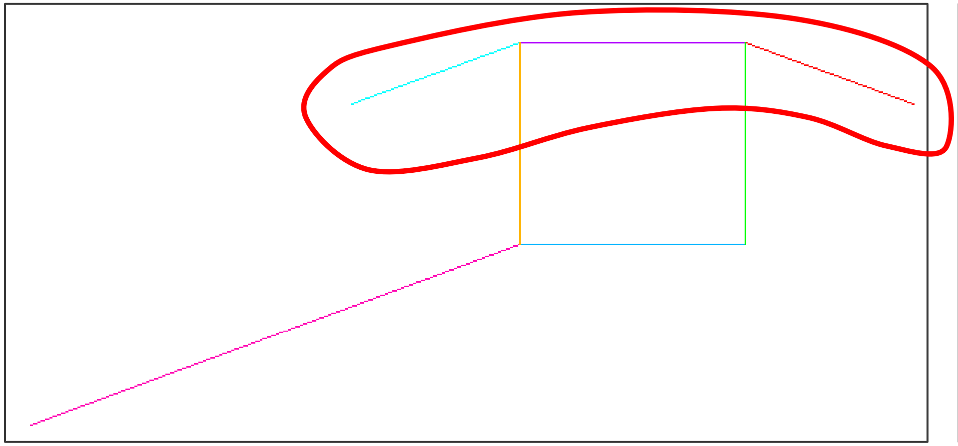
Shared design variables
Each problem has local copies
Co-ordination using augmented Lagrangian

GKN Trollhättan, Chalmers PPU)

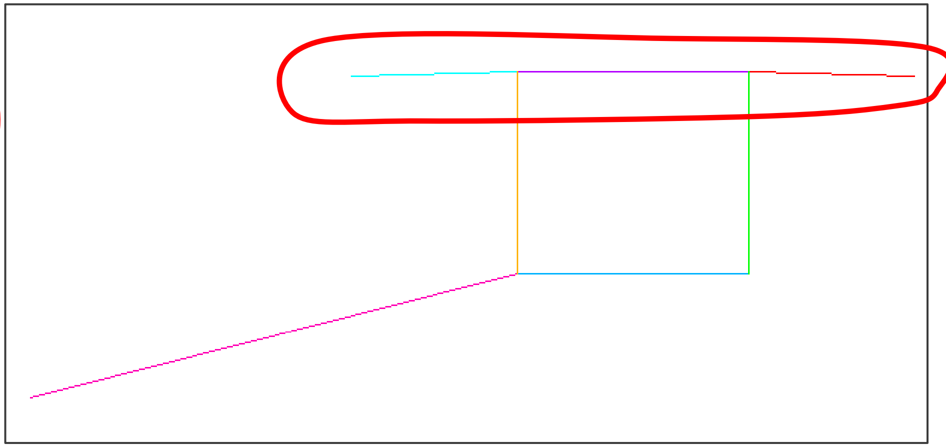
Software

LPT design	:	LUAX-T
Load case FE solver	:	ANSYS 14.0
Optimisation	:	MATLAB 2015

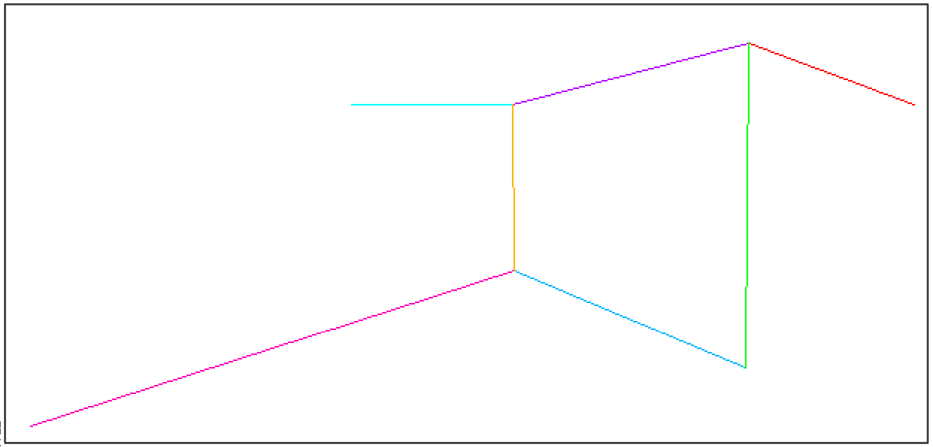
Preliminary Results



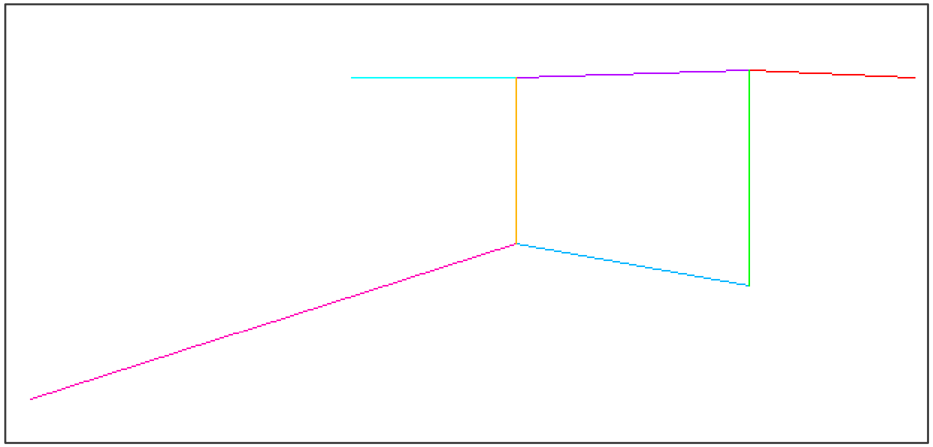
Start point 1



Optimised shape



Start point 2



Optimised shape

Conclusions

- Demonstrated intra-level co-ordination
- Inter level co-ordination needs to be done
  - Requires further target response identification
- Possible starting point for further detailed simulations

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Future works

- Additional levels, additional disciplines
- Look further into component architecture
- Explore links to manufacture of the product

Thank you