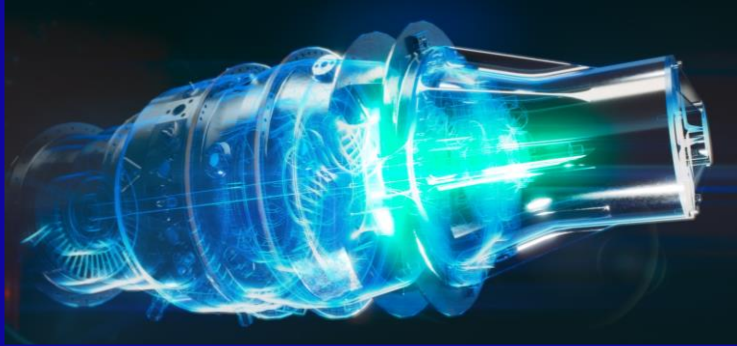


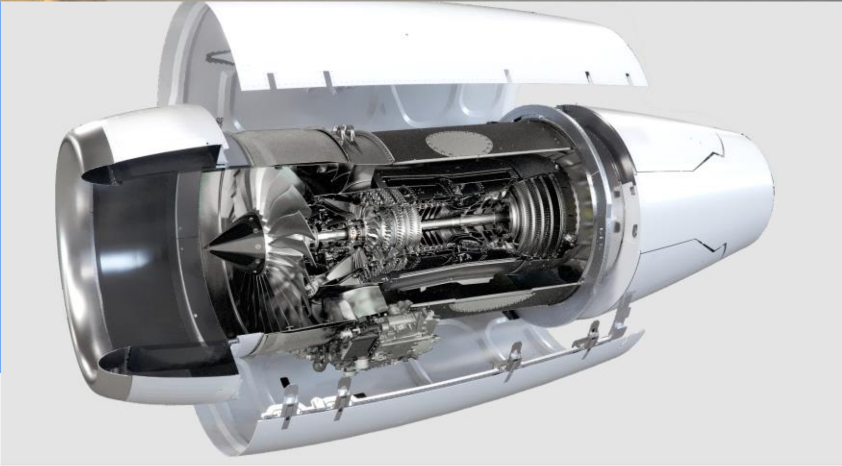
CAESES User Conference

Development of a Flexible Parametric Design System for Small Aero-Engine Centrifugal Compressors

J. Bourgeois

Sept 21, 2022

The activities to enhance the centrifugal compressor design capabilities of Rolls-Royce Deutschland and to develop the manufacturing methods for the new parts were funded in the research program TigHT (Förderkennzeichen 20T1725) in the framework of LuFo V/3 (5th Federal Aviation Research Program call 3)



18,250
Thrust (lbf)

12% better
Thrust-to-weight ratio

5%
SFC reduction

Latest business aviation engines produced at Rolls-Royce Germany

Leading the transition to Net Zero

At Rolls-Royce, we believe there are technological solutions to decarbonising the economy. With the right policy, environment and public support, we have the potential to pioneer game-changing technology that will help deliver a net zero carbon future.

Accelerating our development of electric powered propulsion

Conducting first engine ground tests on 100% unblended SAF

Progressing our SMR programme with secured further funding

Rolls-Royce Electrical sites in Brandenburg – Dahlewitz and Cottbus

Research and development sites for hybrid-electric propulsion systems

Development of hybrid-electric propulsion systems incl new gas turbine technology

CHESCO (Center for Hybrid Electric Systems Cottbus) being established in Lusatia

Future cluster for innovative manufacturing processes, in cooperation with various partners from industry & science, such as the BTU Cottbus-Senftenberg, Fraunhofer and the DLR

~50 direct employees

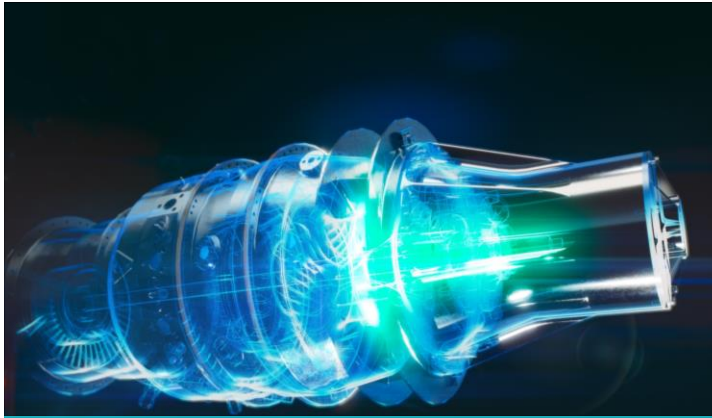
Delivering full portfolio of power and propulsion solutions

We provide complete electric power systems for all-electric and hybrid-electric Advanced Air Mobility vehicles.

Electric propulsion unit, power distribution & energy storage system for Urban Air Mobility

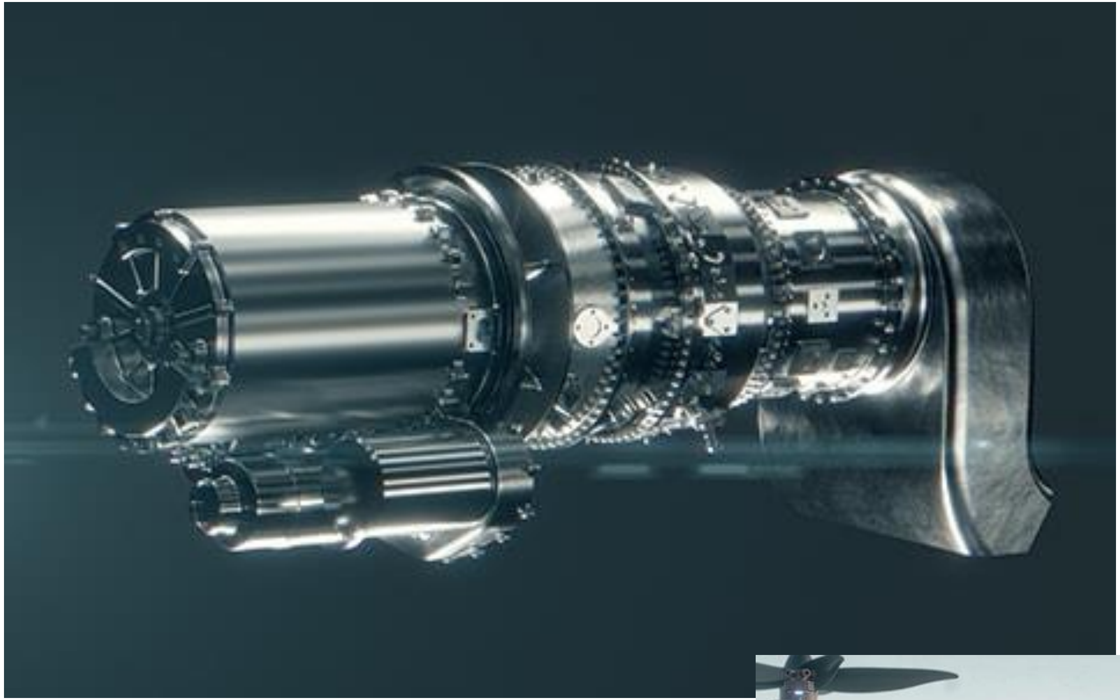
Electric propulsion unit, power distribution & energy storage system for electric commuter aircraft

Aircraft charging and airport infrastructure



Turbogenerator technology

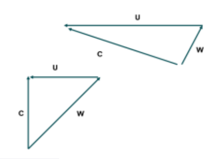
Hybrid Electric Turbo-Generator System



Source: [Press releases | Rolls-Royce - Rolls-Royce advances hybrid-electric flight with new technology to lead the way in Advanced Air Mobility]

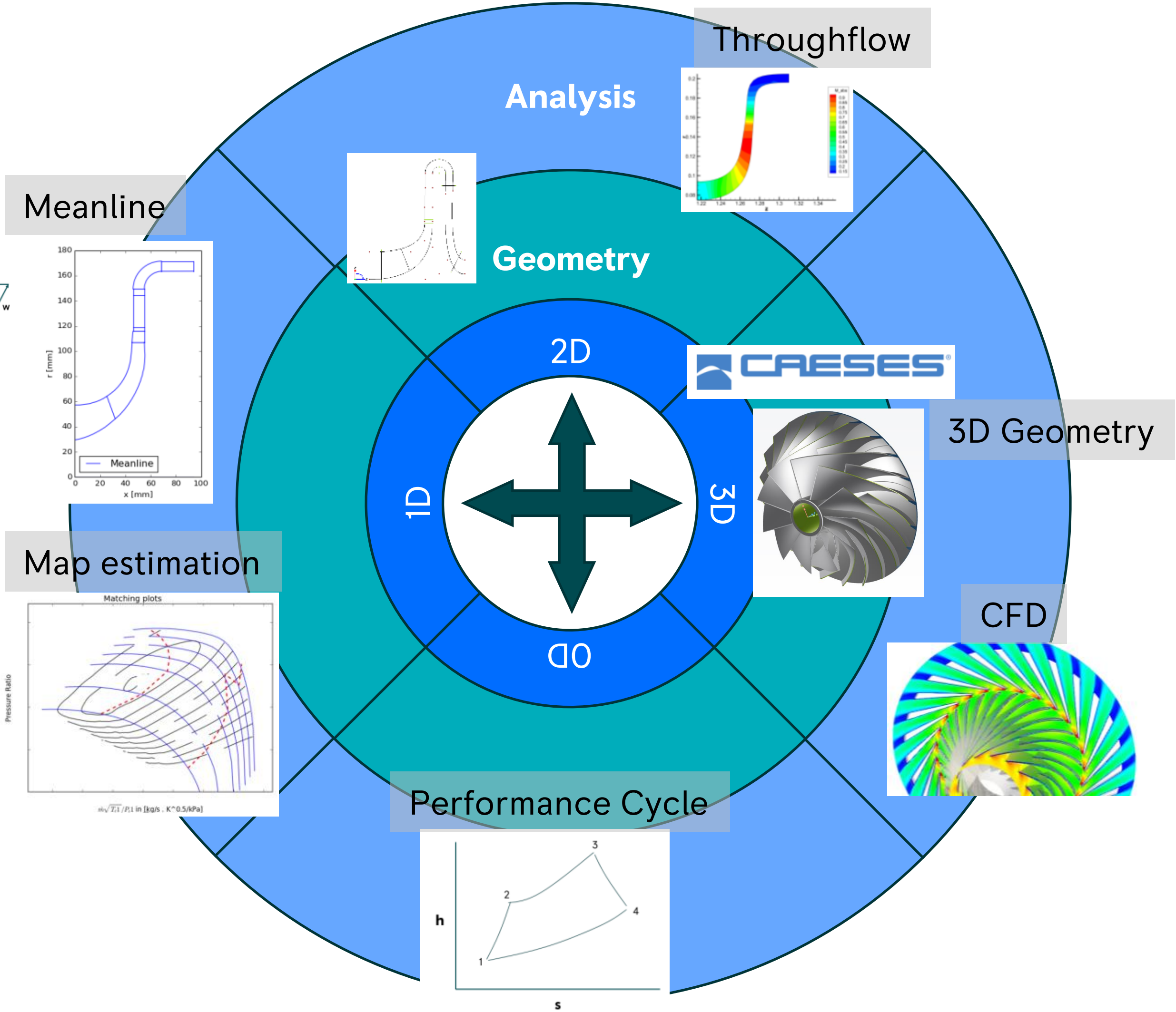
Videos: [TurboGenerator on Vimeo]

Design system needed for Turbo-Generator and other future small engines



The new small engine designs require centrifugal compressors which have not typically been designed at Rolls-Royce Deutschland in recent years,

CAESES chosen for geometry generation due to its customizability, clean parametric modelling approach, and tool connections available with meshing (Cadence AutoGrid & ANSYS TurboGrid), optimization tools, and workflow tools (ANSYS Workbench)



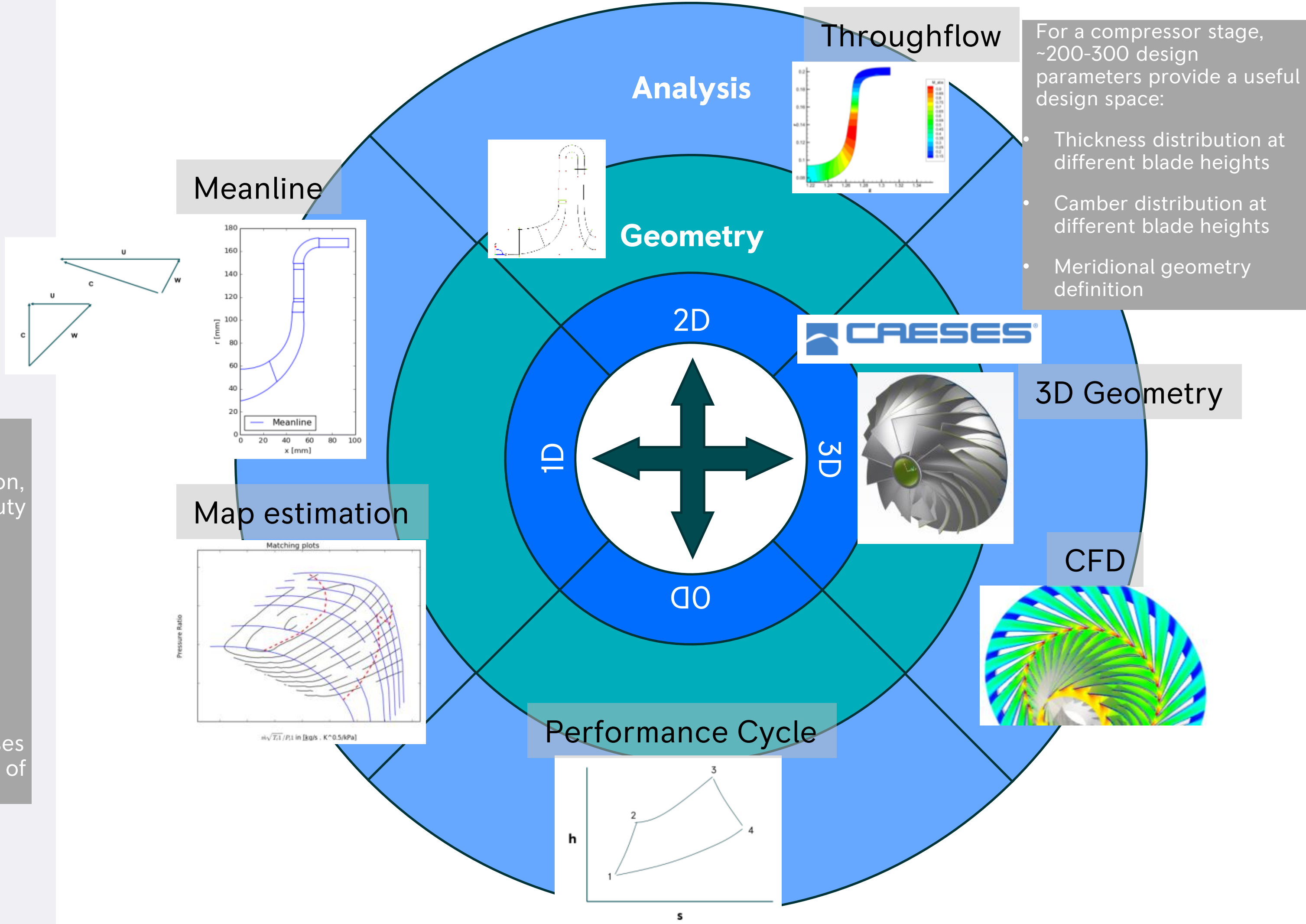
Aero-engine compressor design

- Over the design cycle of an engine, many iterations are done with a large multi-disciplinary team.
- Some of the main drivers for compressor design are:
    - Minimize weight
    - Maximize efficiency
    - Meet flow and pressure-ratio targets
    - Ensure compressor stability
    - Ensure fatigue and stress limitations of compressor
    - Minimize cost
- Different levels of fidelity are needed during the design iterations of the engine
    - Low fidelity meanline calculations give fast answers and can be filled with correlations to understand how designs need to change with different assumptions.
    - Medium fidelity throughflow and blade-to-blade analyses can help quickly get blade designs narrowed down close to target.
    - High fidelity CFD can be used for more accurate design assessment and detailed parameter space exploration.

Design system needed for Turbo-Generator and other future small engines

During design iterations with other engine components (combustor, turbine, installation, air system), the compressor duty (pressure ratio, flow) may change and requires adjustments.

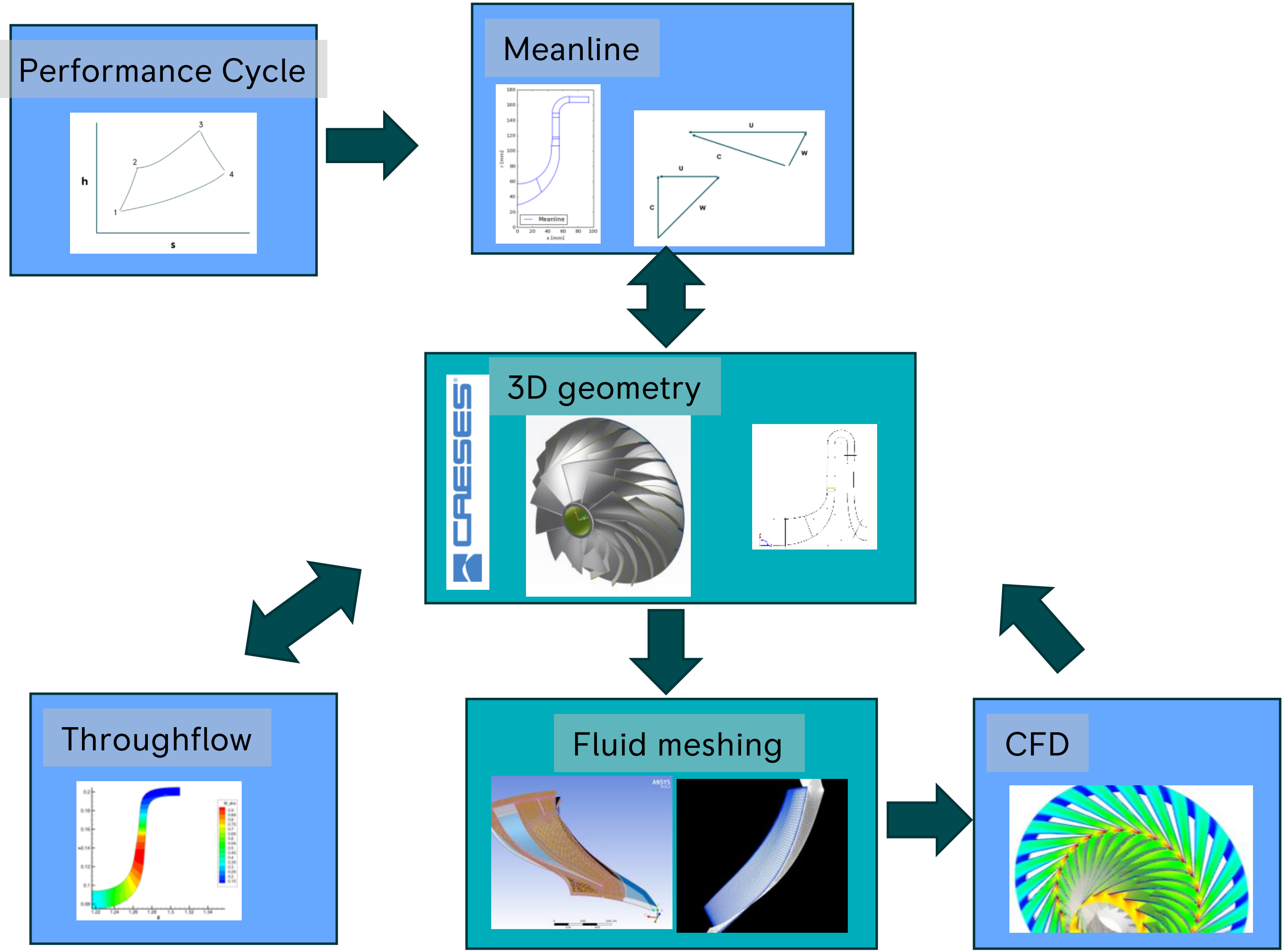
It is incredibly useful to tie together tools in the design system to be able to share parameters and update analyses rapidly for the different levels of fidelity!



Workflows needed for design system:

Aerodynamic design

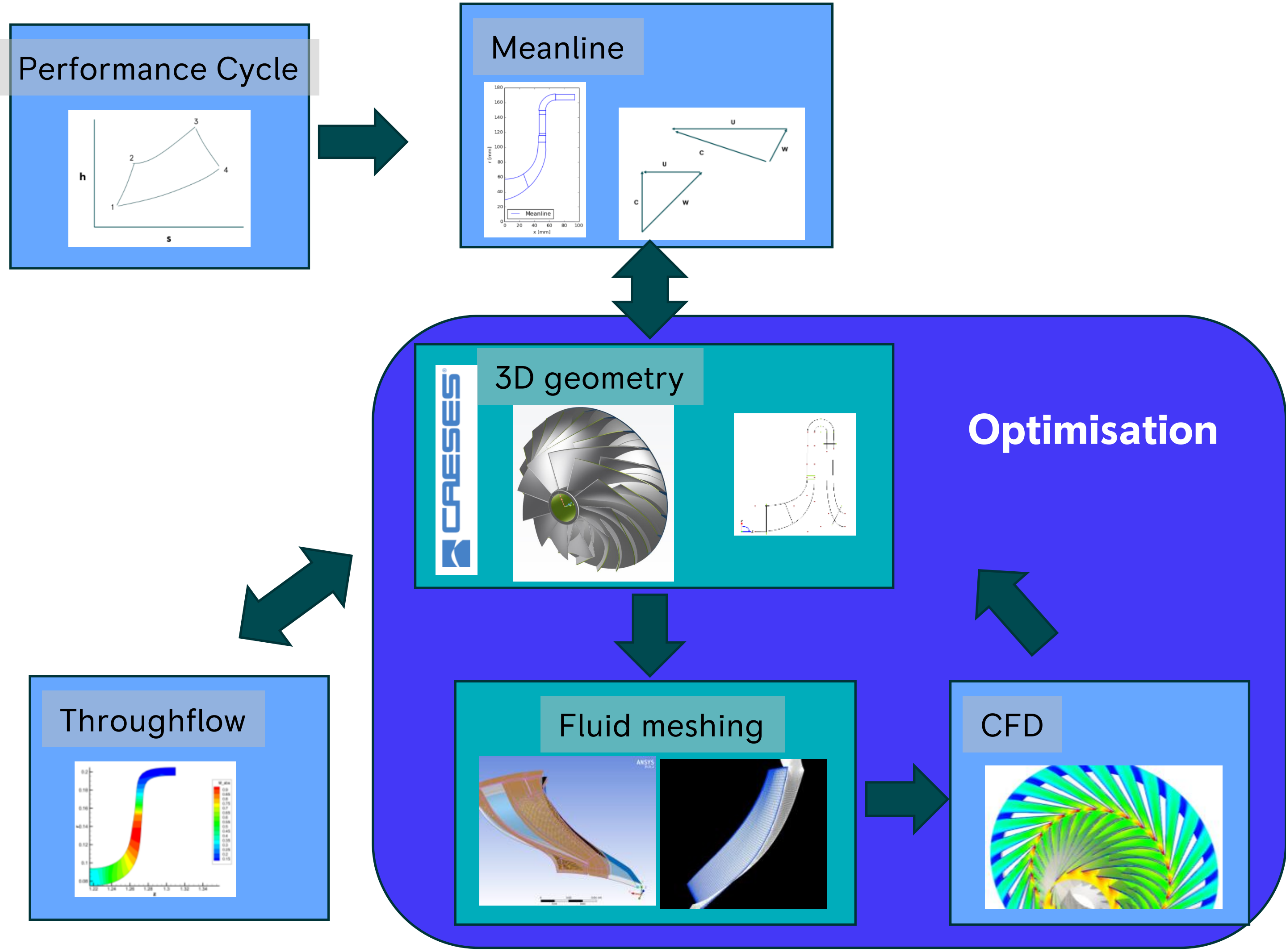
With a target of the compressor duty, typically aerodynamic iterations can be done to get a good design of the blading in the component to achieve the targets and maximize efficiency.



Workflows needed for design system:

Aerodynamic design

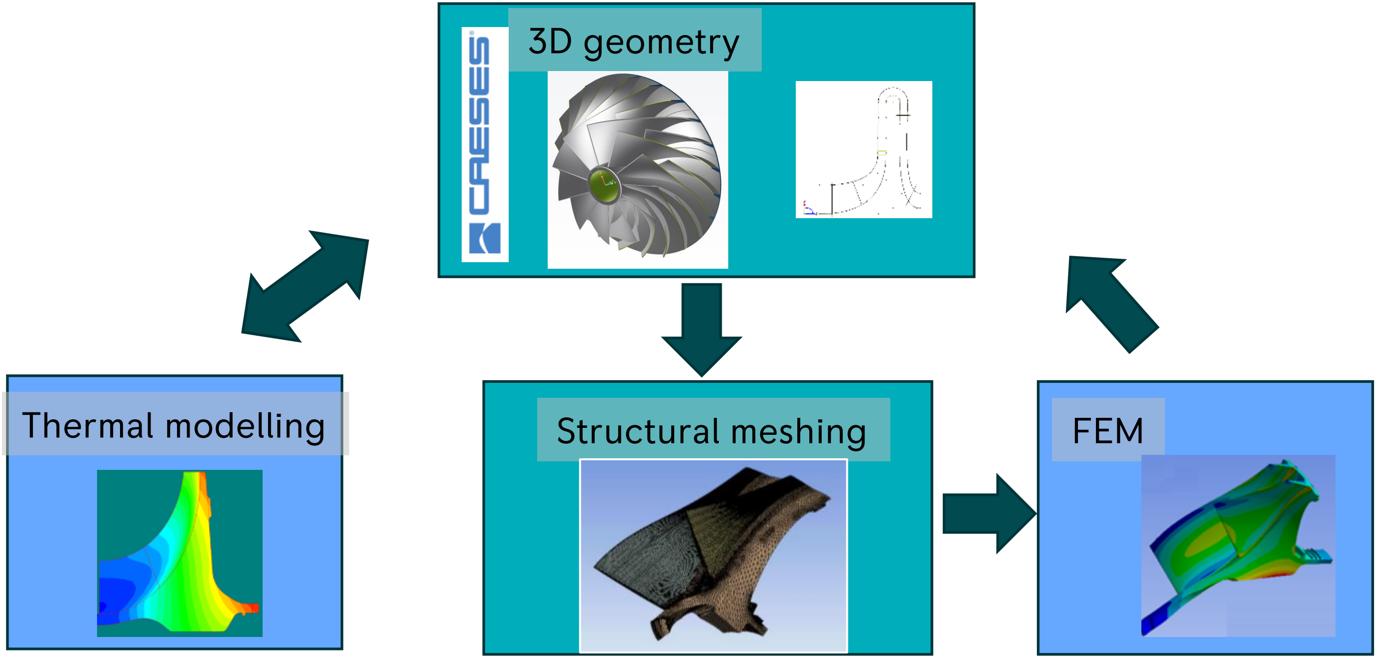
Impellers can have quite complex flow structures, and the aerodynamic adjustments of the blading and evaluation with CFD can be wrapped in an optimisation loop to evaluate large numbers of candidates.



Workflows for design system:

Stress analysis

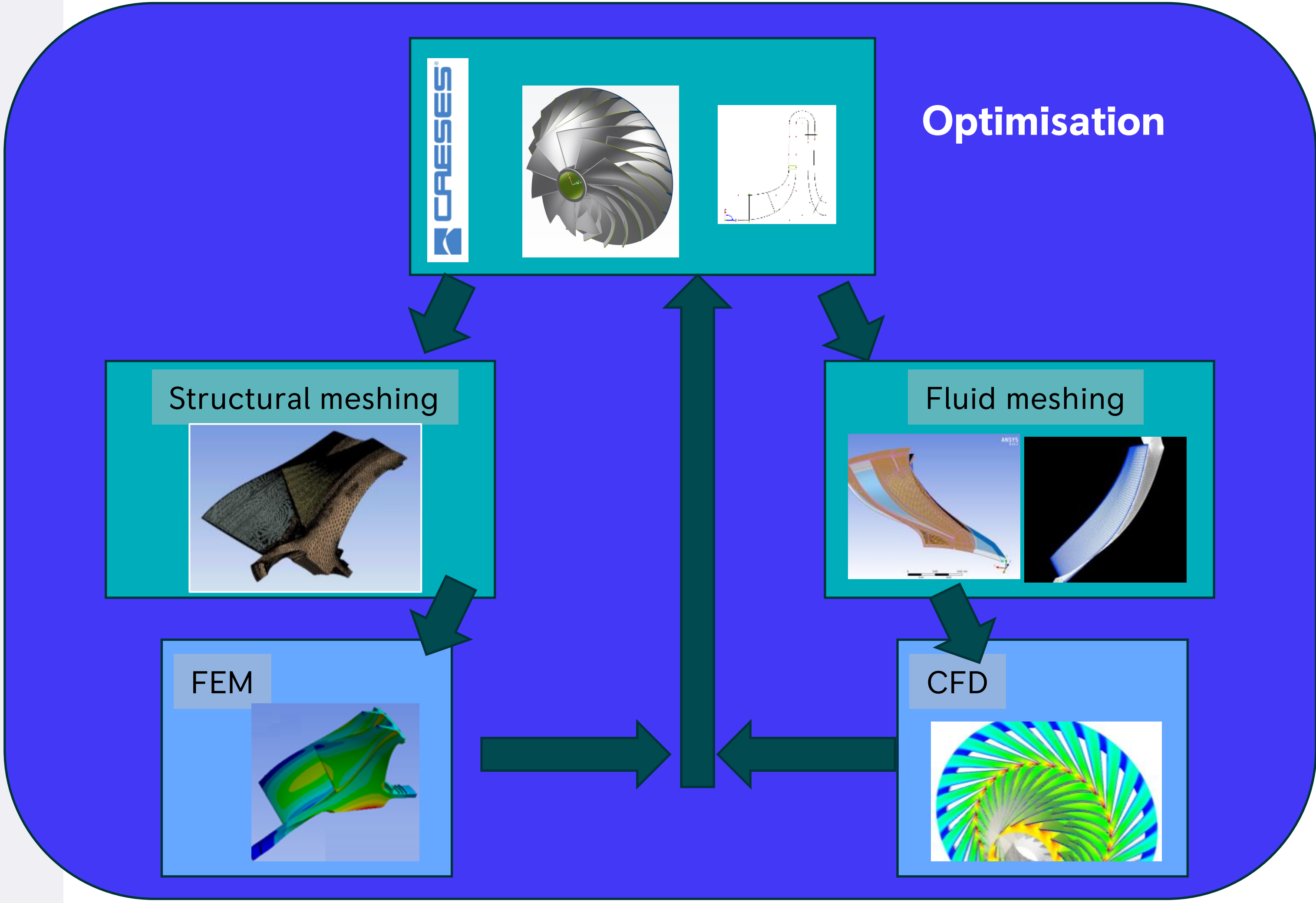
The shape and speed of impeller blading can result in high stresses if one is not careful. Finite element modelling in conjunction with thermal modelling is needed to ensure a life and mechanical integrity.



Workflows for design system:

Joint Stress & Aerodynamic Optimisation

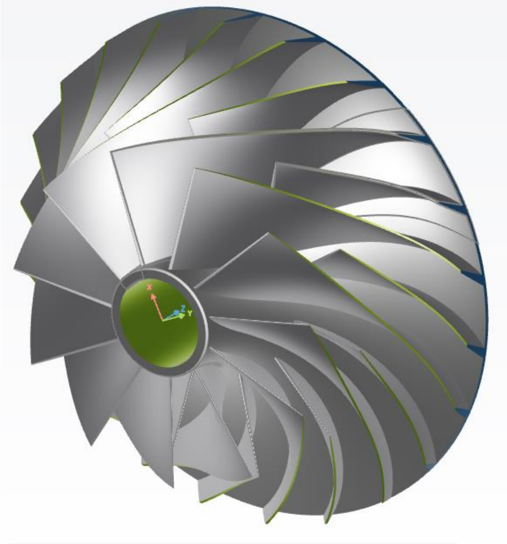
Although complex, one of the most useful optimisation schemes will run both aerodynamic and stress analyses together to come to a design that is both efficient and mechanically robust (while penalizing higher weight due to aerospace requirements).



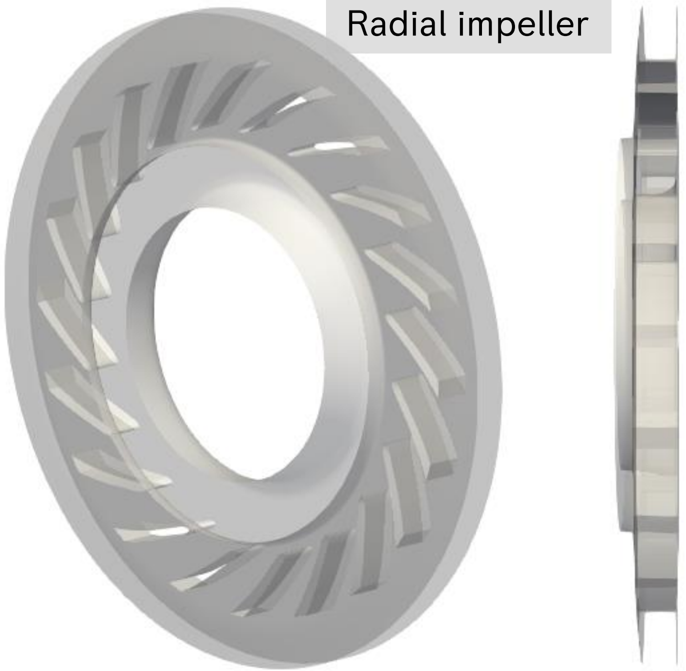
Design flexibility:

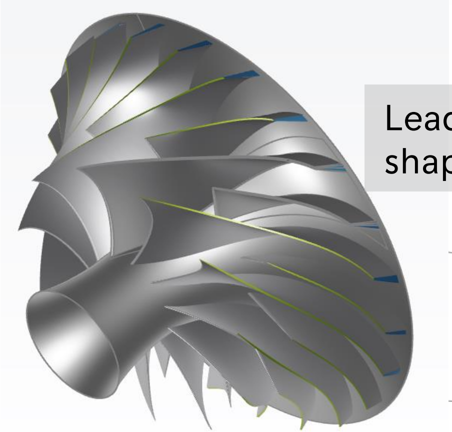
Impellers

Centrifugal impeller (with splitter)

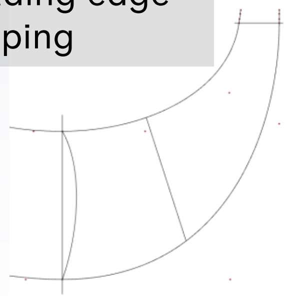


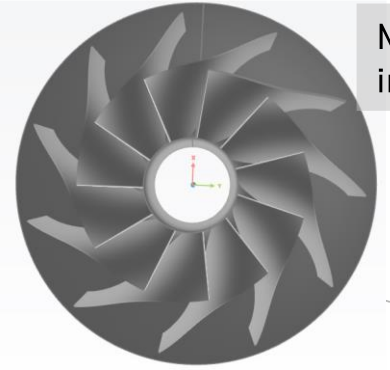
Radial impeller



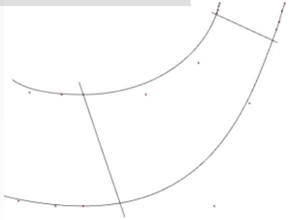


Leading edge shaping





Mixed flow impeller



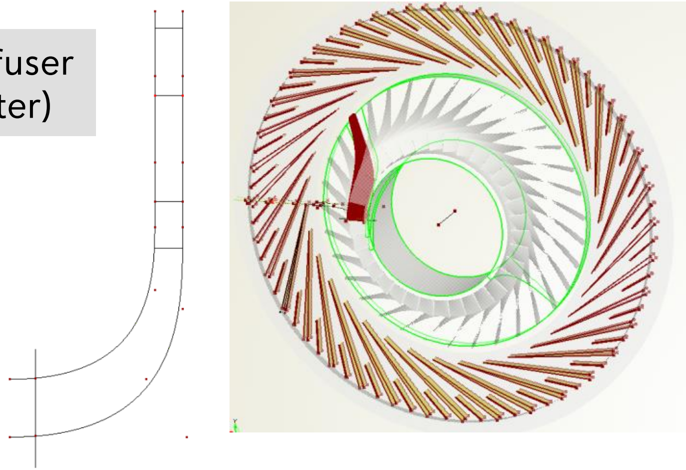
CAESES open parameterization allows endless opportunities to explore various blade topologies and more detailed shaping, as is deemed appropriate.

It is a challenge to ensure parameter expansions and different options can be kept compatible with the rest of the design system.

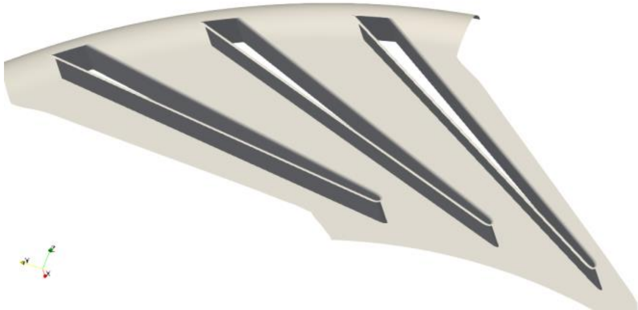
Design flexibility:

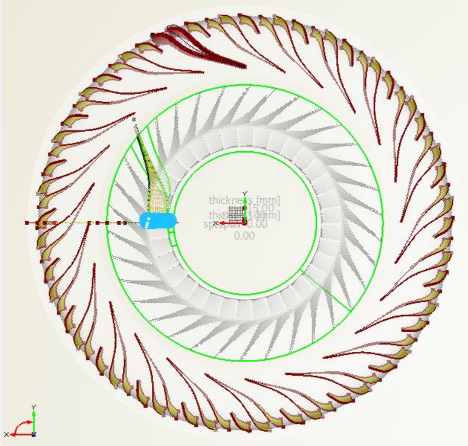
Diffusers

Radial diffuser (with splitter)

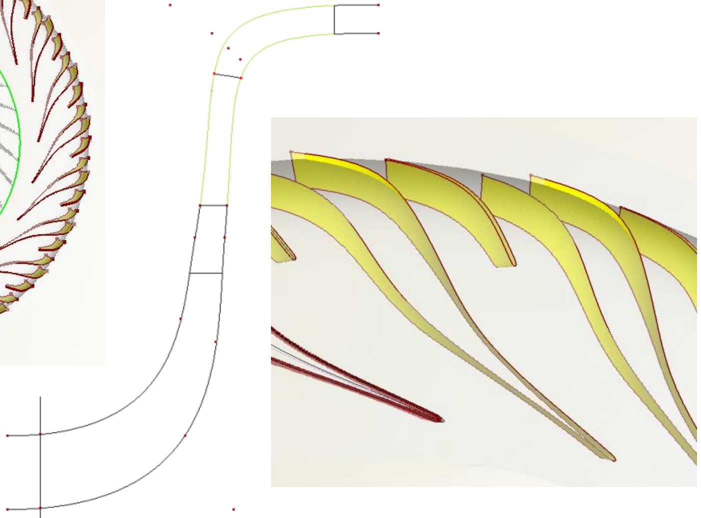


Radial wedge diffuser

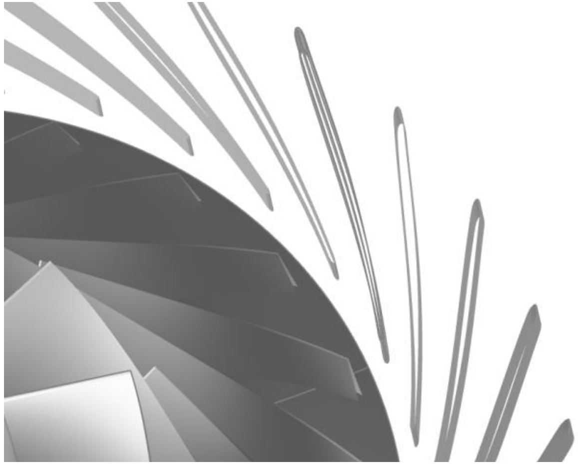




Passage diffuser (with splitter)

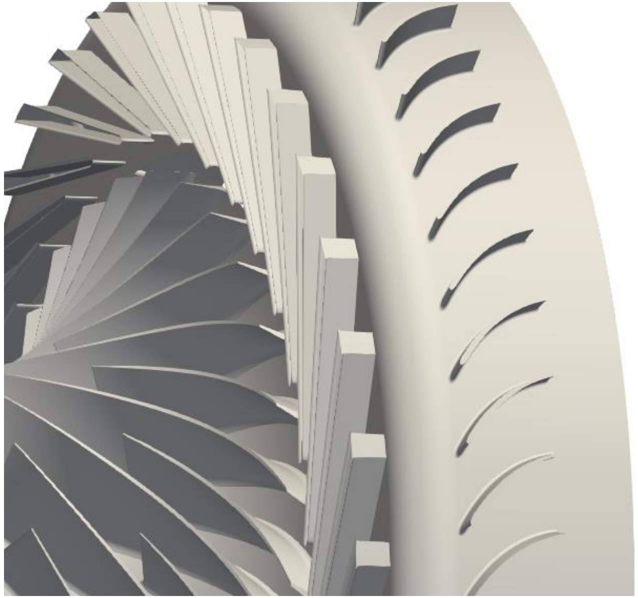


Radial diffuser with airfoils

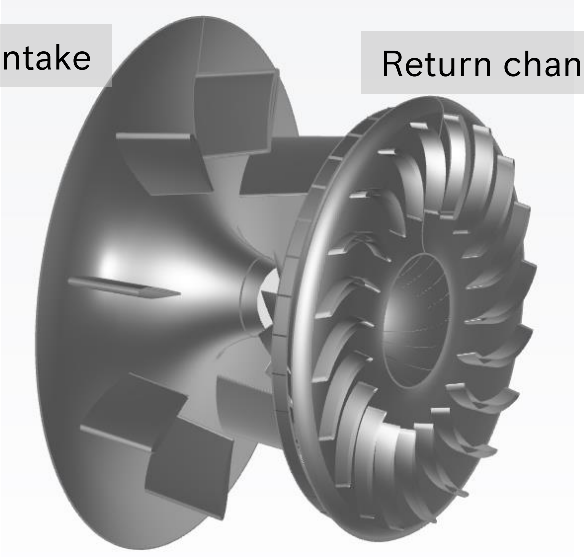


Design flexibility:

Other static components


Deswirl cascade

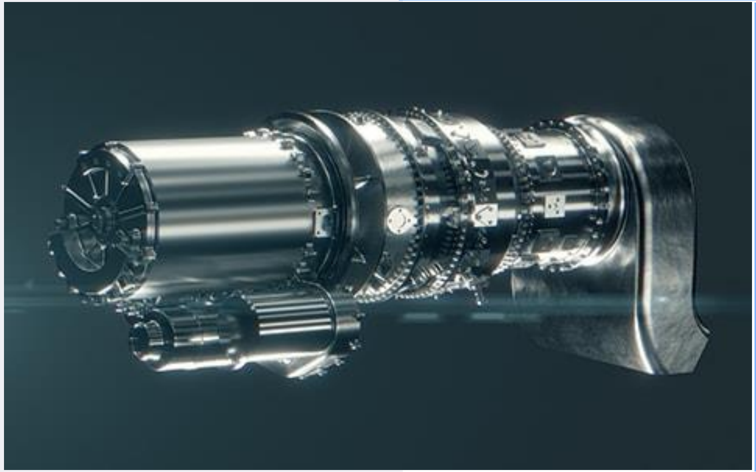

Volute


Intake

Return channel

Conclusions

- New small engine demonstrator has been designed which will run for the first time this year.
  - Plenty of learning will come from this demonstration that will applied in the subsequent stages of the development program.
  - Designs will be improved and applications to deploy the design will be targeted.



- The centrifugal compressor aerodynamic design system has been developed with CAESES as the geometry engine.
- Further work with CAESES:
  - Continue improving CAESES model capabilities (geometry options, robustness of features, detailed parameterizations)
  - Apply optimisation workflows for future product designs.