

ECL-B3

A new UHBR fan test-rig for aerodynamic, aeroelastic and aeroacoustic studies



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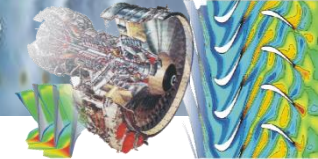
Sébastien Goguey

Gilbert Halter

Pierre Laucher

Lionel Pierrad

Benoit Paoletti



Turbomachinery Platform at ECL

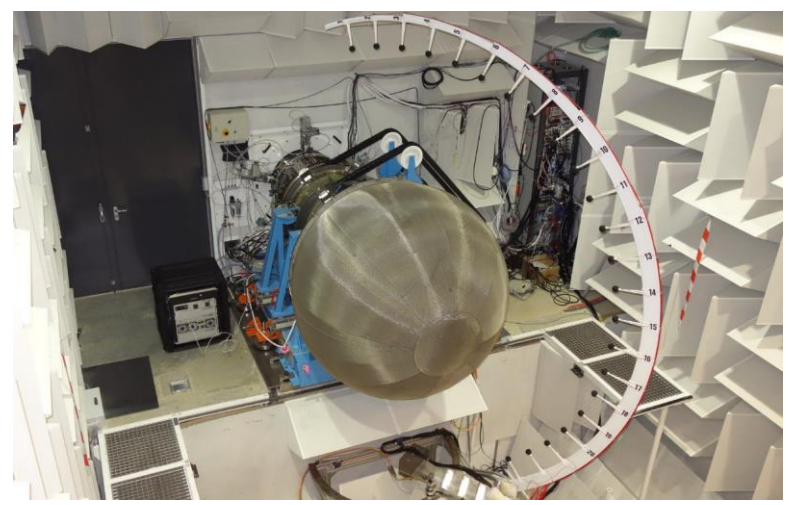
High Speed Test rigs

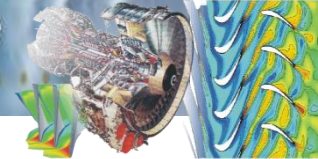


ECL-B3 (3MW)
Project PHARE-2
UHBR Fans

ECL-B2 (2MW)
Project CREATE
Multistage Axial Compressor

ECL-B1 (1MW)
Project TURBOCEL
Centrifugal Compressor

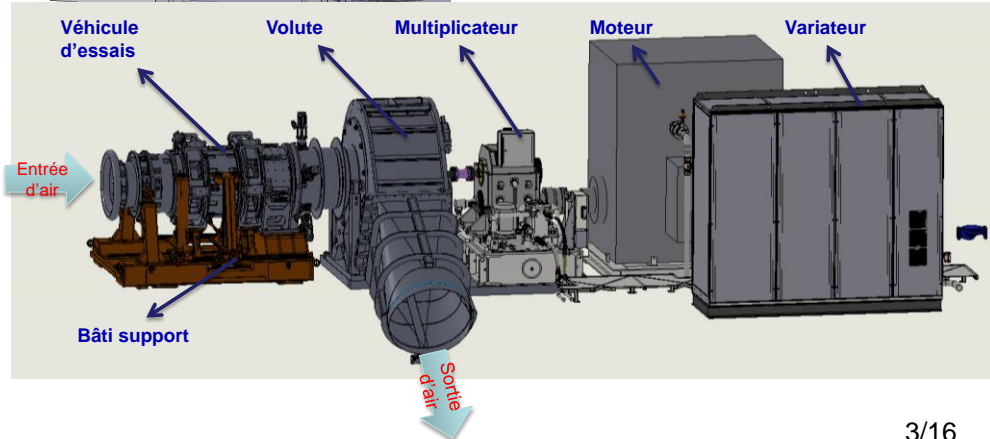
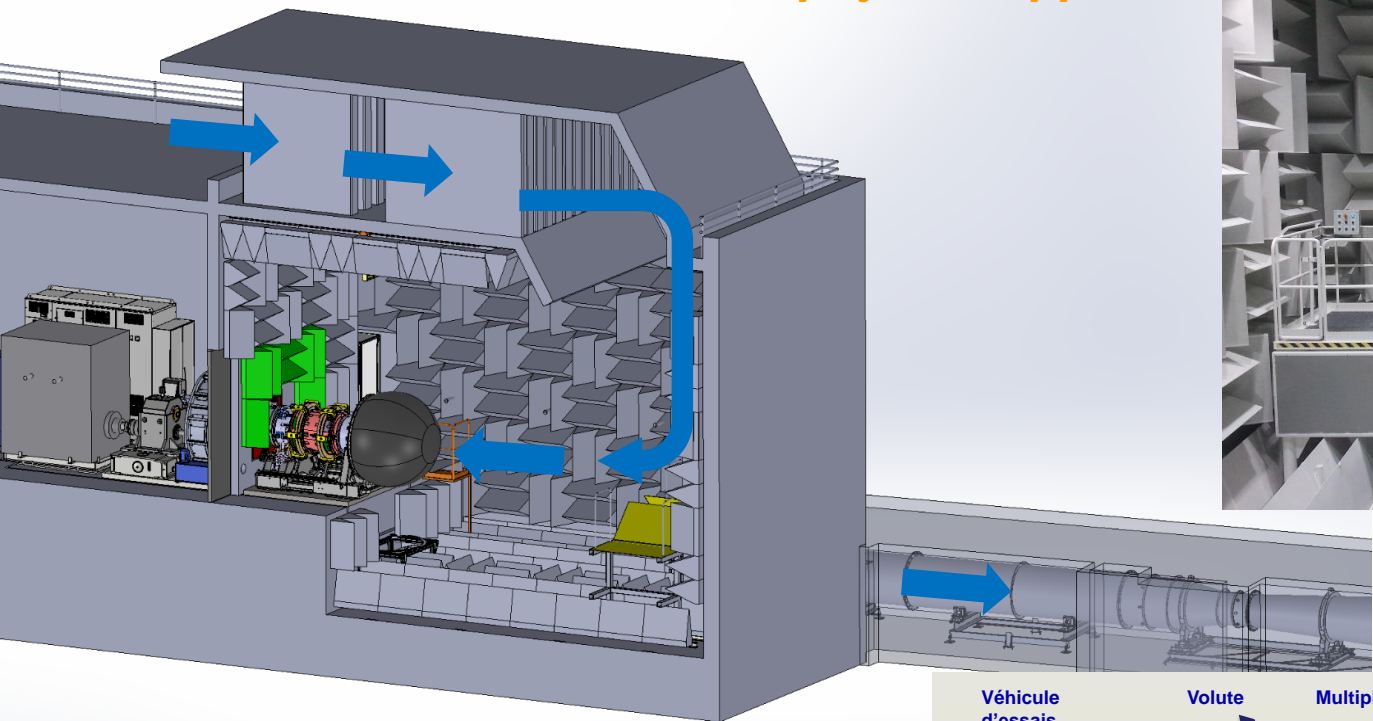




ECL-B3 test rig

Scale 1/3 for UHBR composite fan

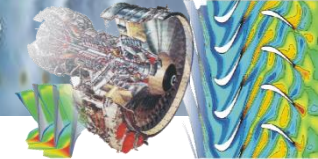
multi-physical approach



Characteristics

- Max mass flow: 45 kg/s
- Max pressure ratio N_n : 1.8
- Min pressure ratio: 0.5 N_n low
- Max rotation speed: 16200 rpm
- Max Power: 3.0 Mwatt

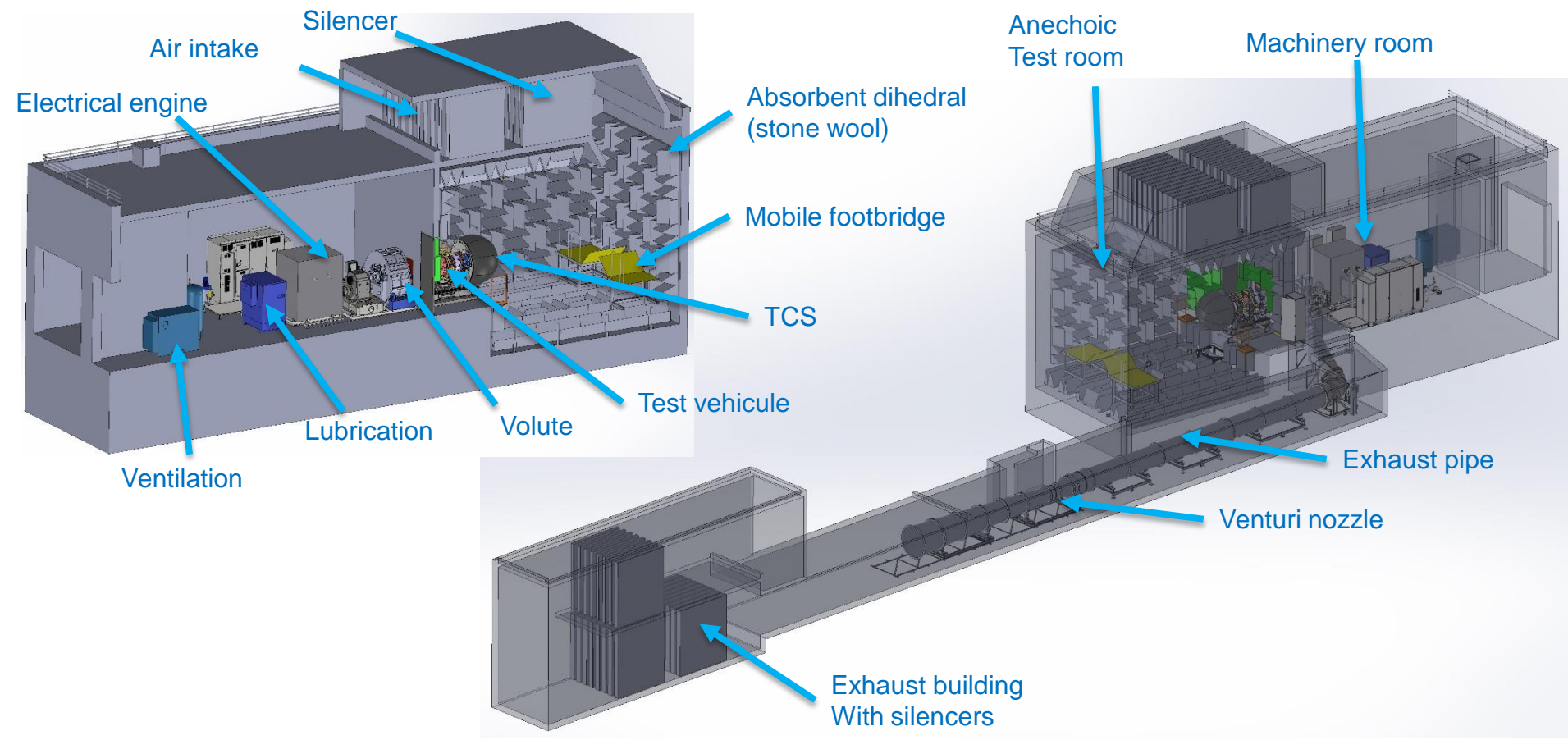
Designed for RS and surge studies

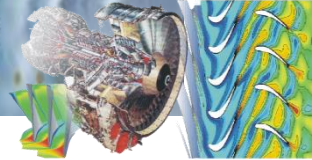


ECL-B3 test rig

Scale 1/3 for UHBR composite fan

multi-physical approach

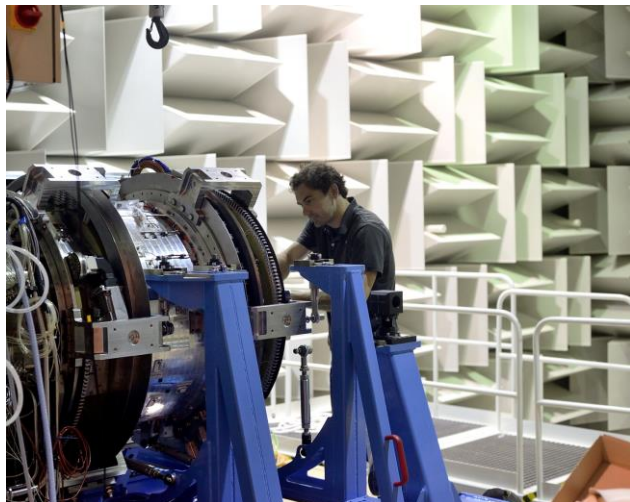


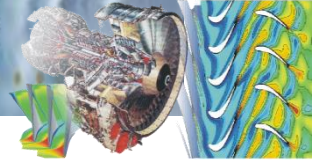


ECL-B3 test rig

Scale 1/3 for UHBR composite fan

multi-physical approach





ECLB-3: A test rig dedicated to fans

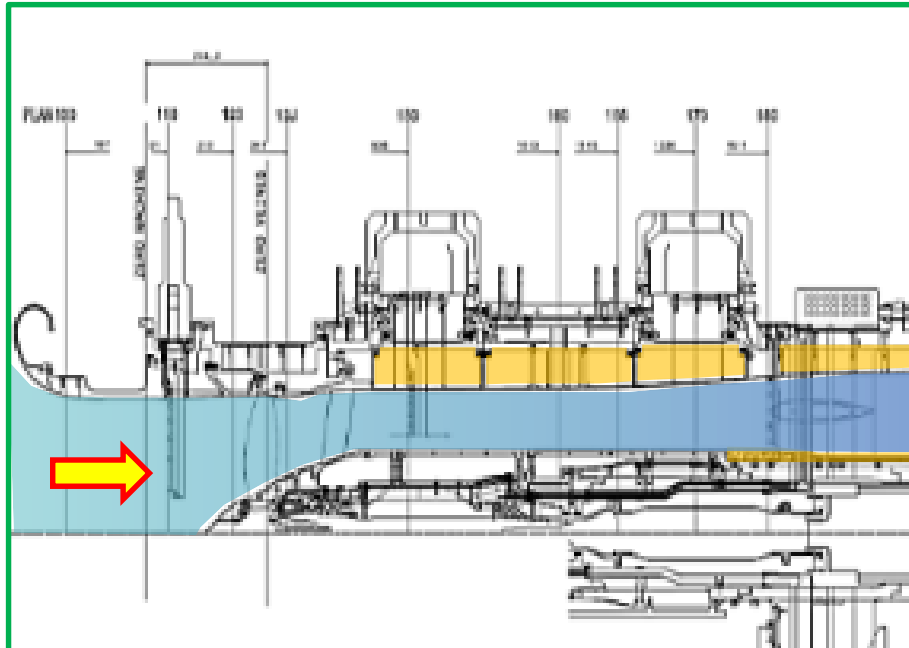
■ The test vehicle

- Manufactured by Safran
- Only one flow path (no bypass ratio)
- Highly parametric capability (fan, OGV, casing, hub, air intake...)
- Full 360 measurements (3 rotating rings)
- Can integrate pylon and non-axisym conf.
- Hub cantilevered: make the changes easier

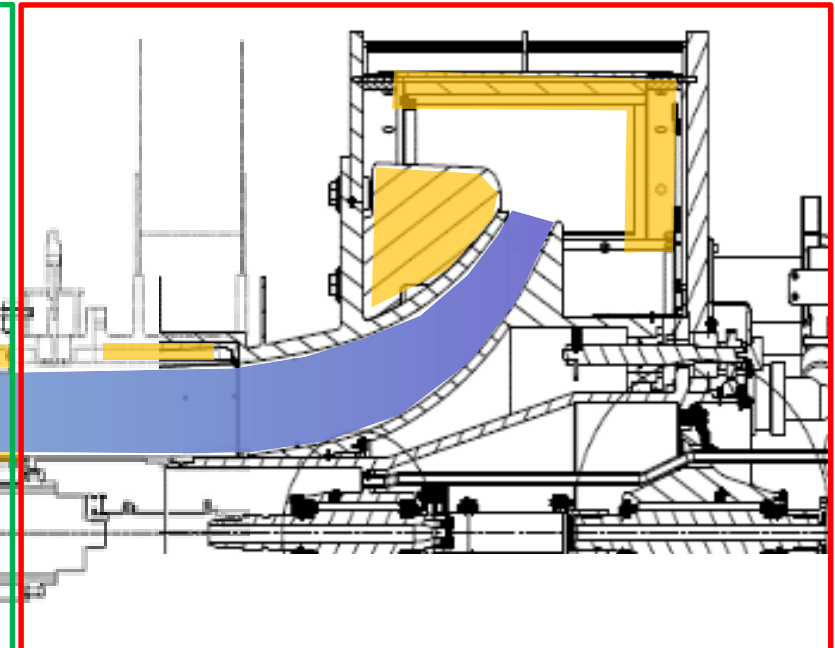
■ The volute (collector)

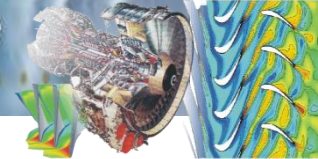
- very few loss: necessity for the OP with very low pressure ratio
- Control of the OP : Specific study for the downstream throttle
- Avoid any non-axisymmetric effects
- Acoustic behaviour !
- Mechanical behaviour of the shaft line !

Test vehicle



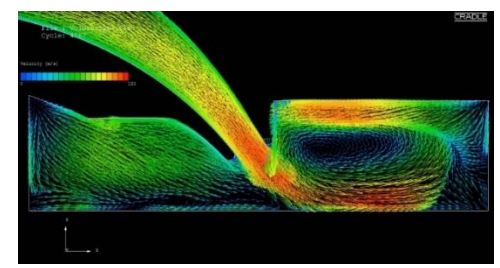
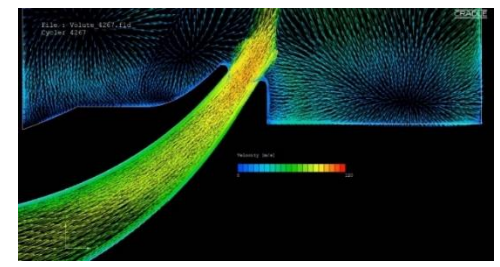
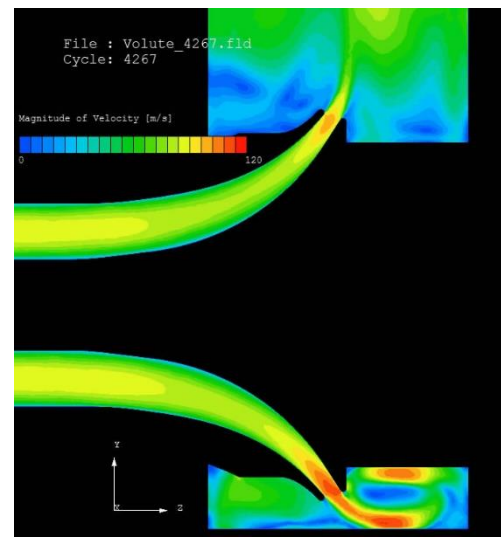
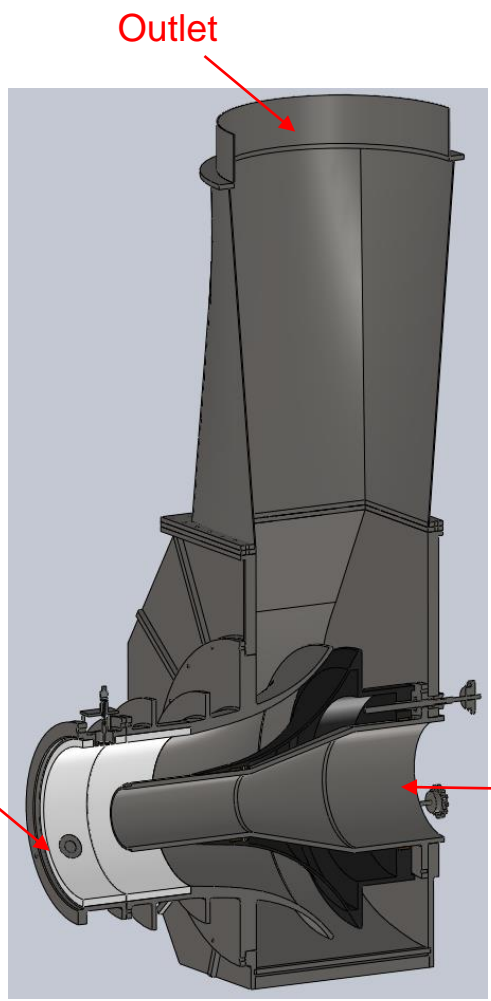
Volute





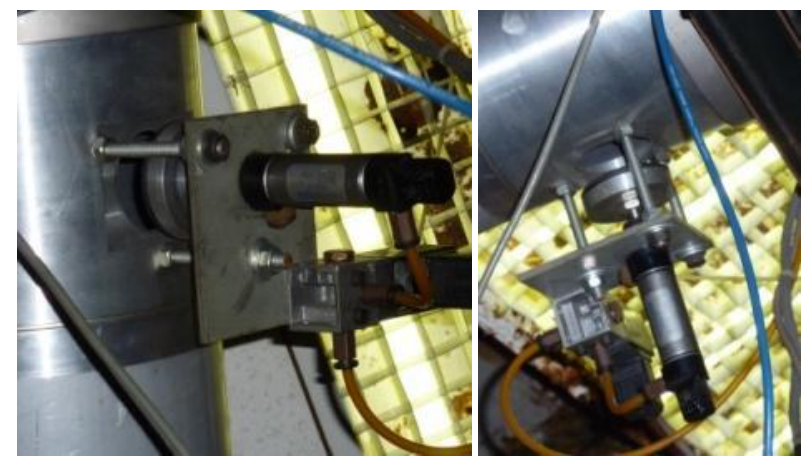
ECLB-3: volute and throttle valve

- Aerodynamic design optimization

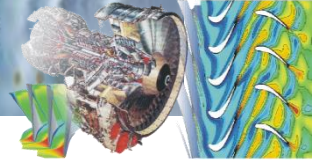


Diffuser shape and losses calculation versus hub position (throttling)

Throttle
Axisymmetric
Moving hub

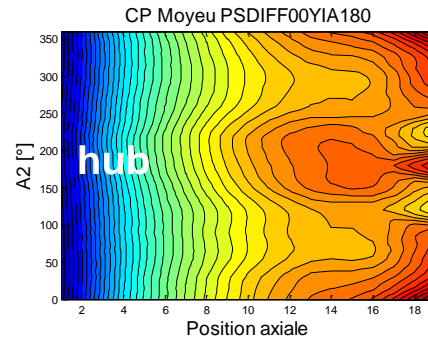
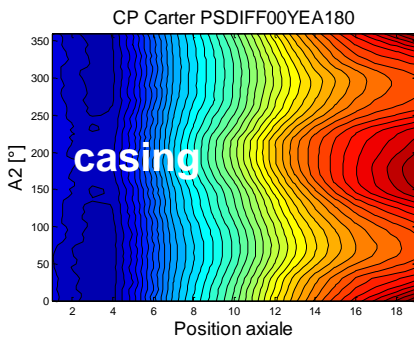
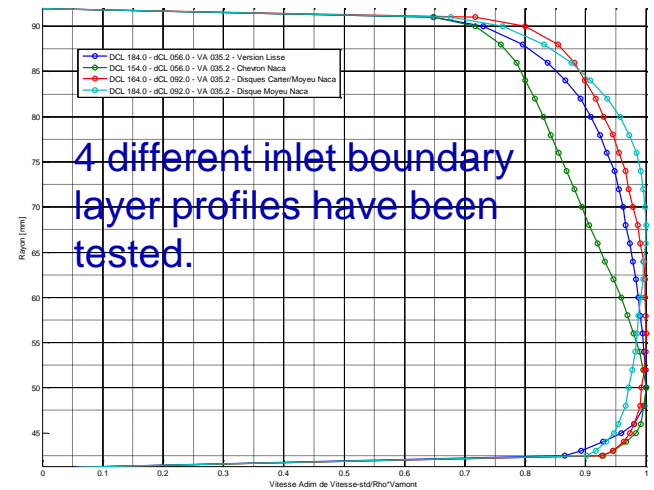
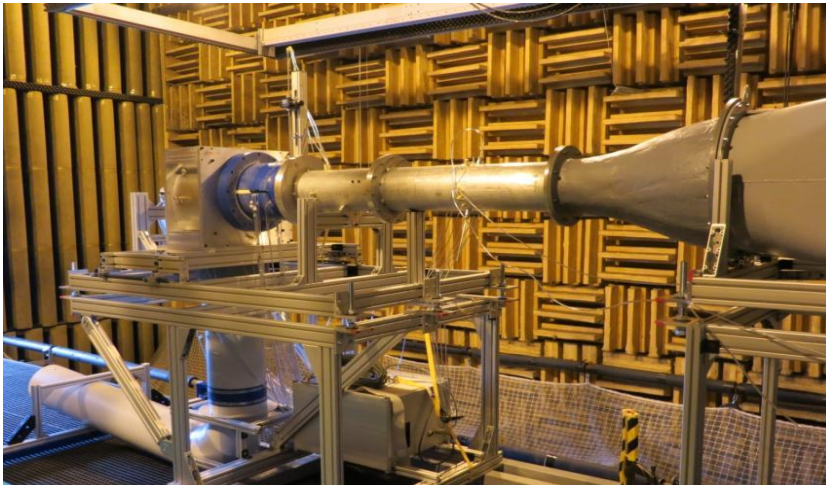


Emergency bleed valves (6 valves)

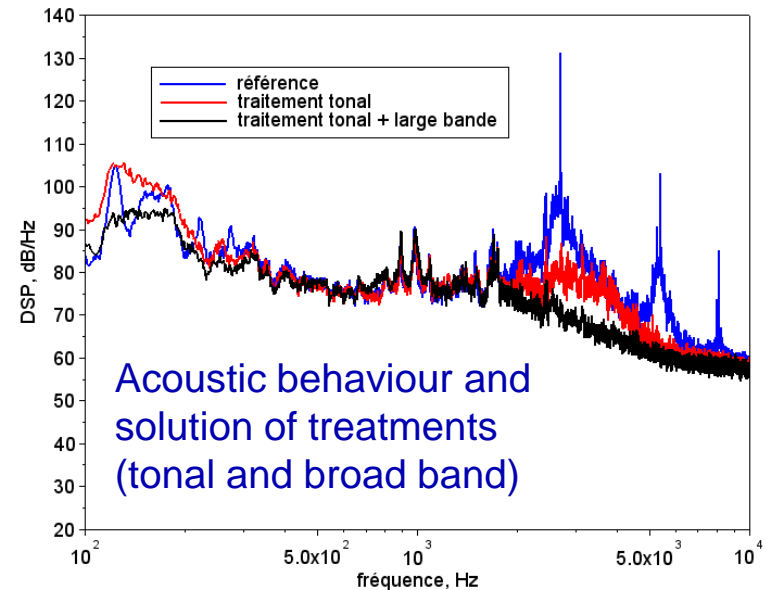


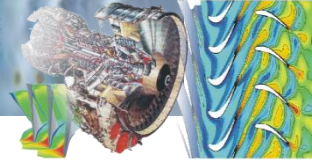
ECLB-3: volute and throttle valve

- Aerodynamic and acoustic measurements using a model (scale 1/3)



Presence of a non-uniformity at the volute outlet, that is dumped towards the inlet. Only 1.2% of change is measured in the circumferential distribution of the Cp coefficients.





Acquisition system

Total today : **809 channels**

■ Dynamic acquisition system: National Instrument

- 33 gauges (OGV and rakes in 110/150)
- 44 high frequency response sensor $p(t)$
- 47 vibration sensors
- 3 sensors for the rotation speed
- 4 sensors for the axial force
- 11 torque meter
- 17 Tip timing + 9 tip gap meas.

■ Acquisition system (low frequency)

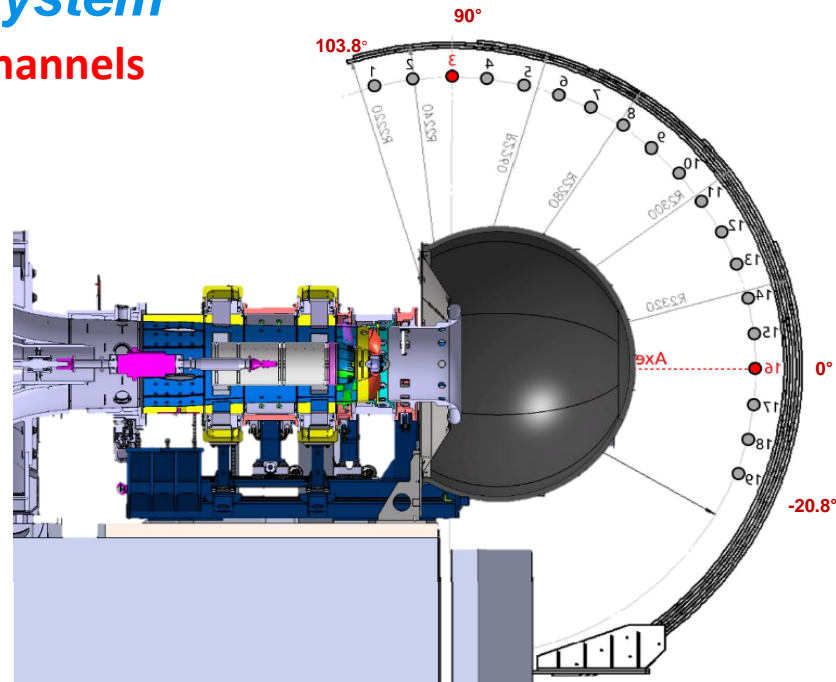
- 305 pressure measurements
- 114 temperatures measurements
- 32 temperatures (cold point compensation)
- 3 P + 1 T Venturi nozzle

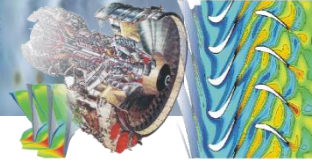
■ 186 microphones acquisition system: National Instrument

- 153 machine
- 23 antenna + 6 volutes + 4 test-room

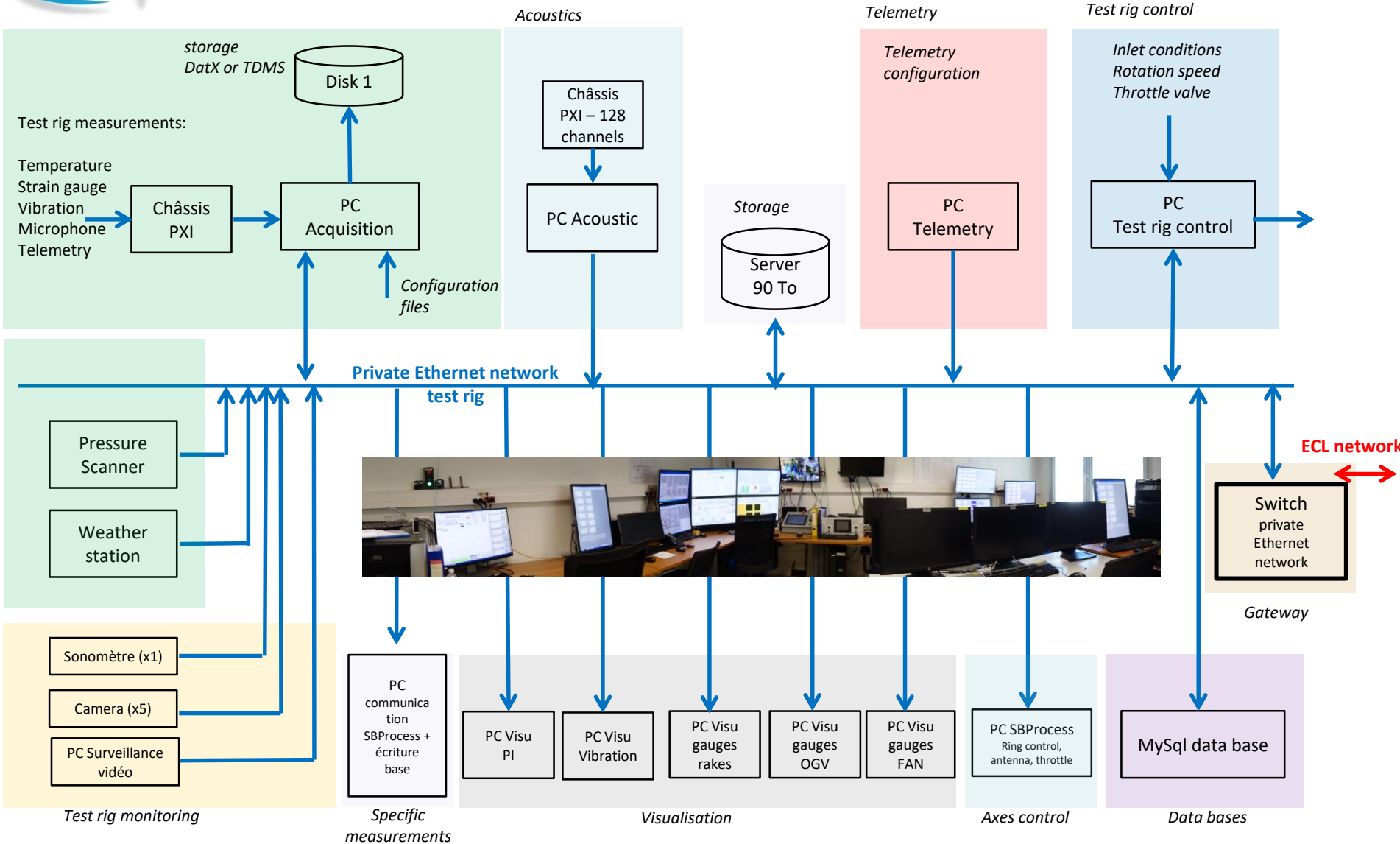
■ Telemetric system

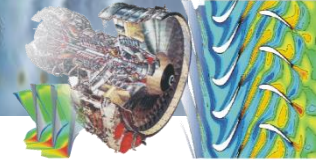
- 16 gauges for the configuration at the moment (22 possibilities)



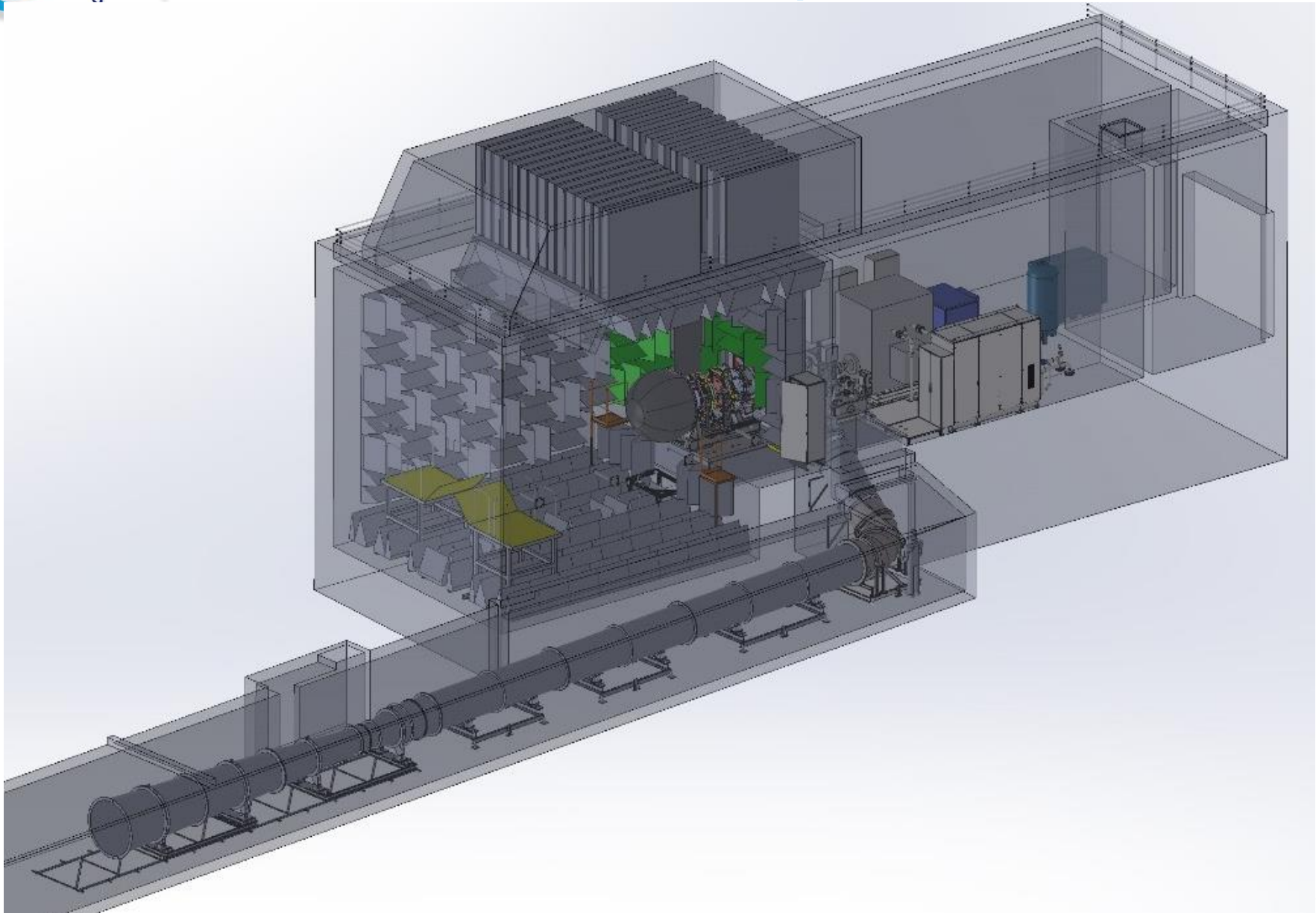


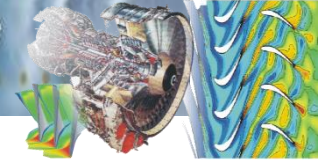
Acquisition network



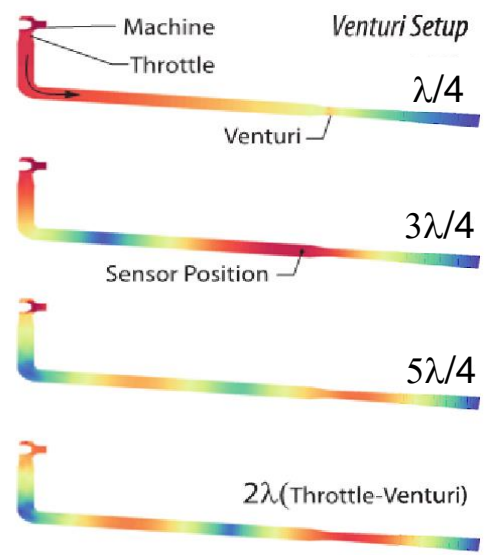
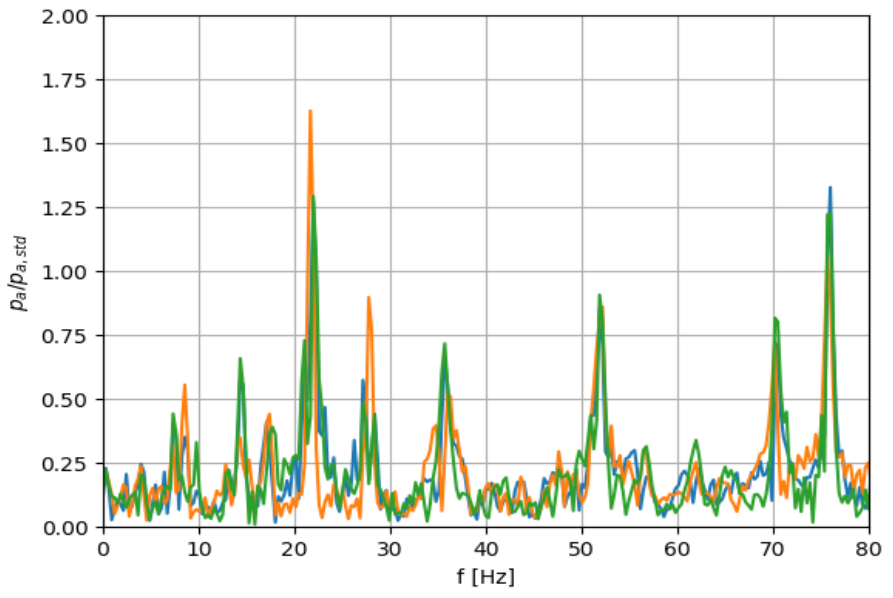
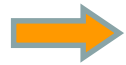


A fantastic trumpet





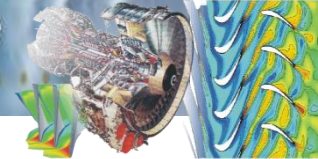
Acoustic of the exhaust pipe



Calculations of the acoustic modes on both for the test rig and the model.

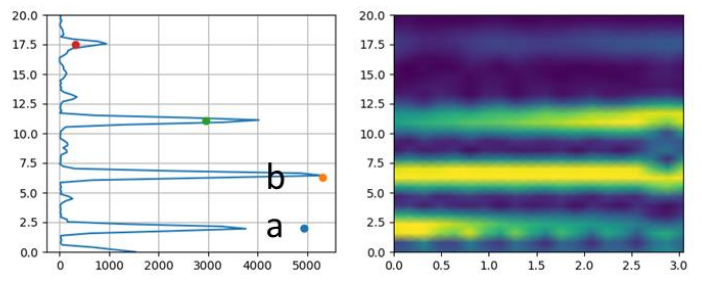
Definition of Helmholtz resonators (one per frequency to dump).



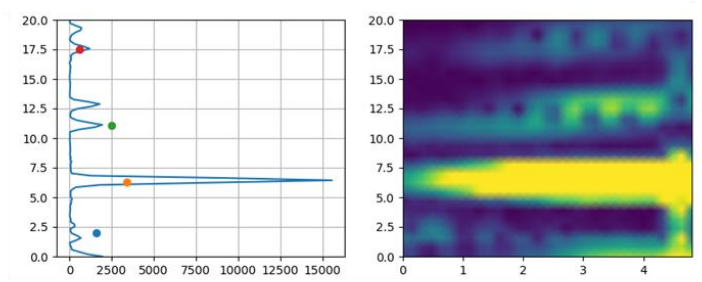


Acoustic treatment

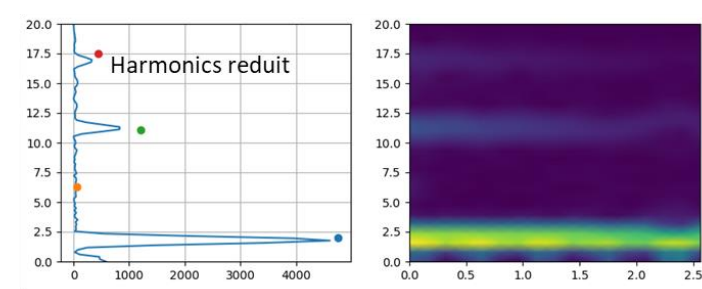
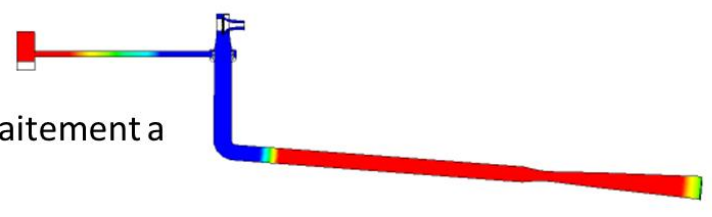
Helmholtz resonators



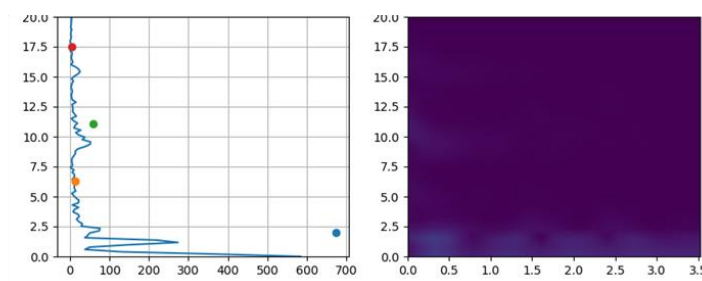
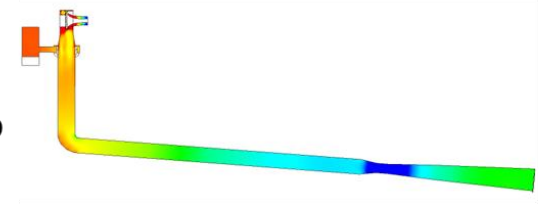
No resonator



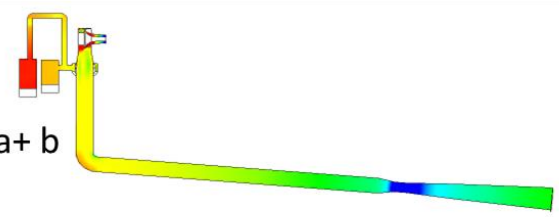
Traitement a

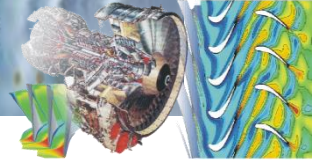


Traitement b

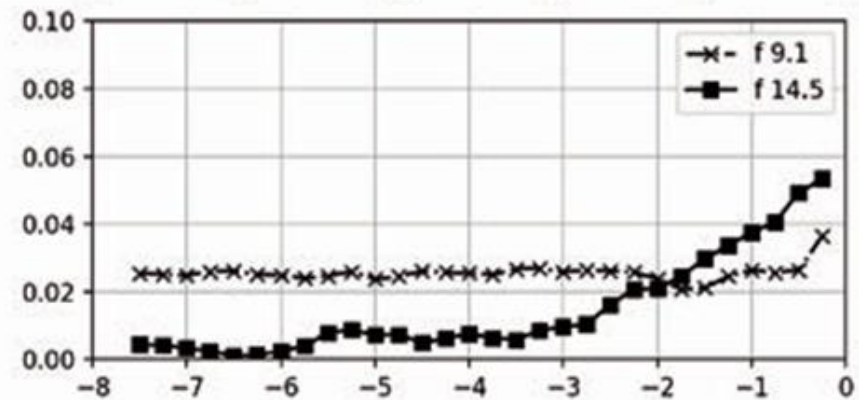
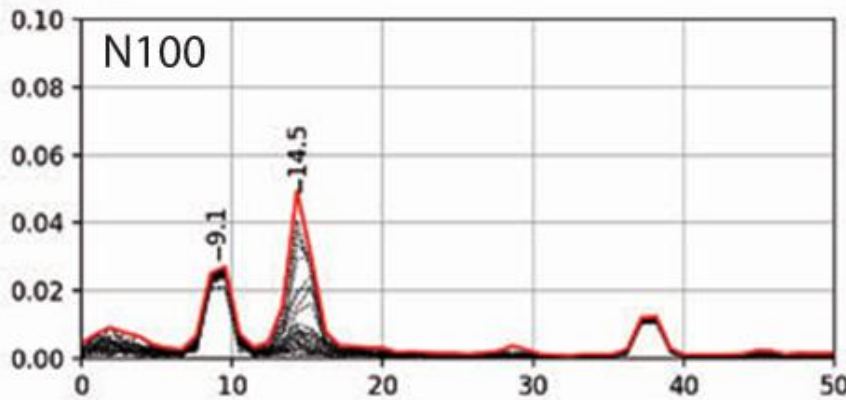
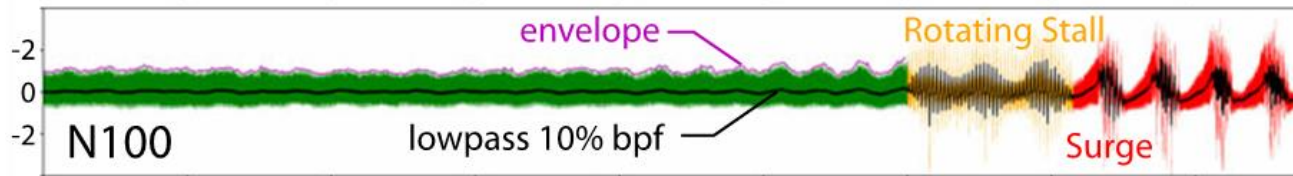


Traitement a+ b

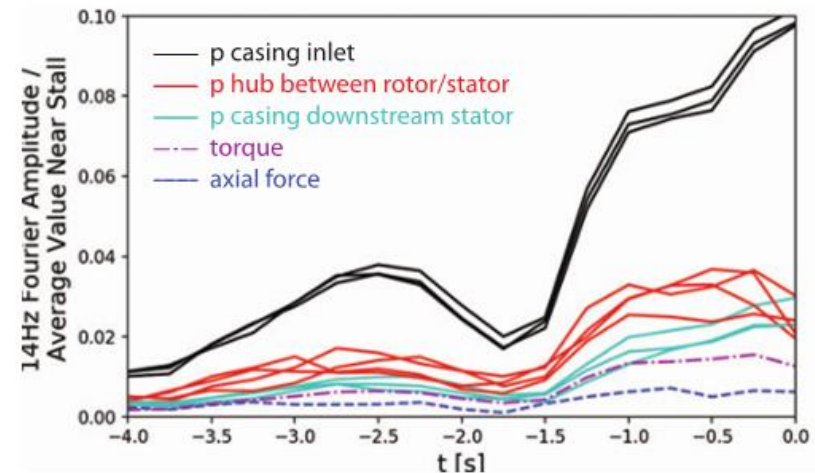


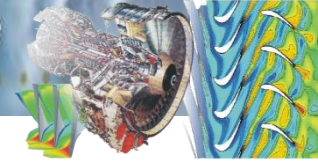


Instabilities onset

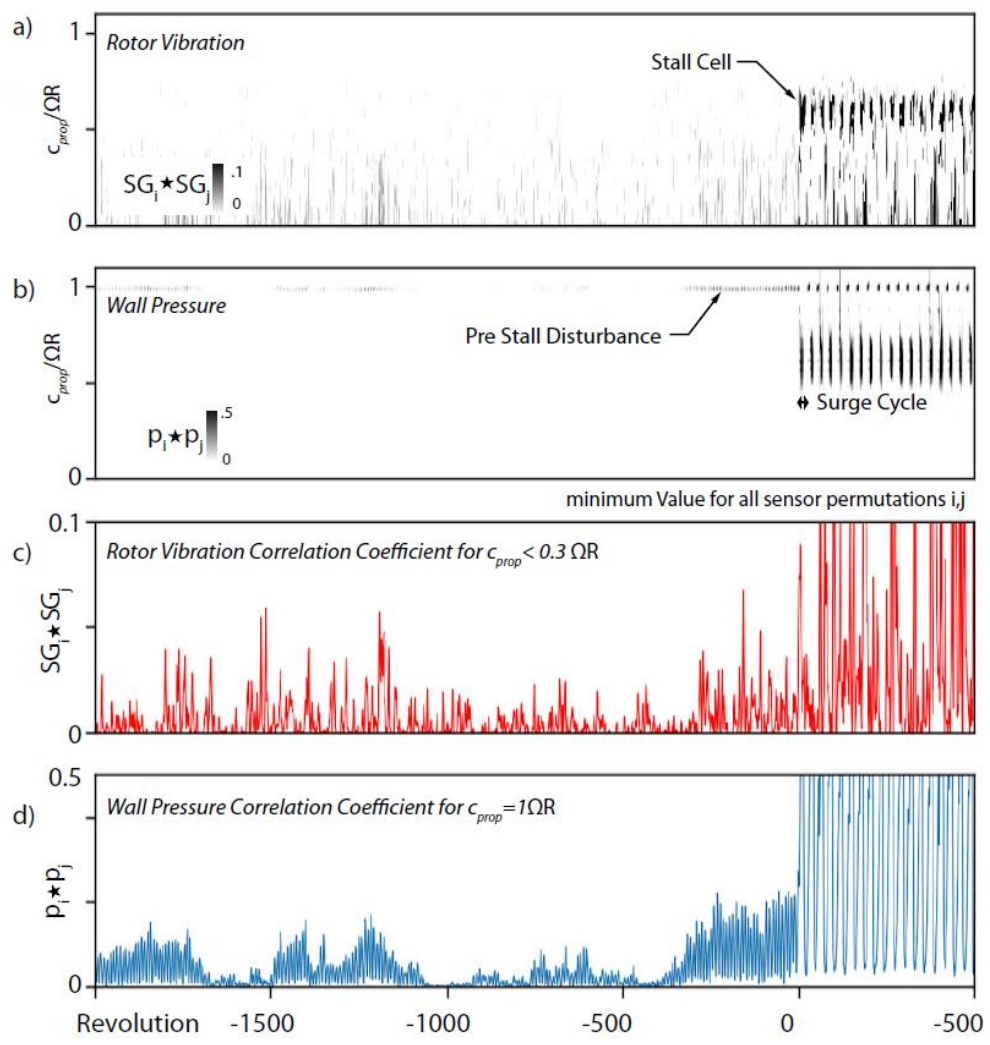
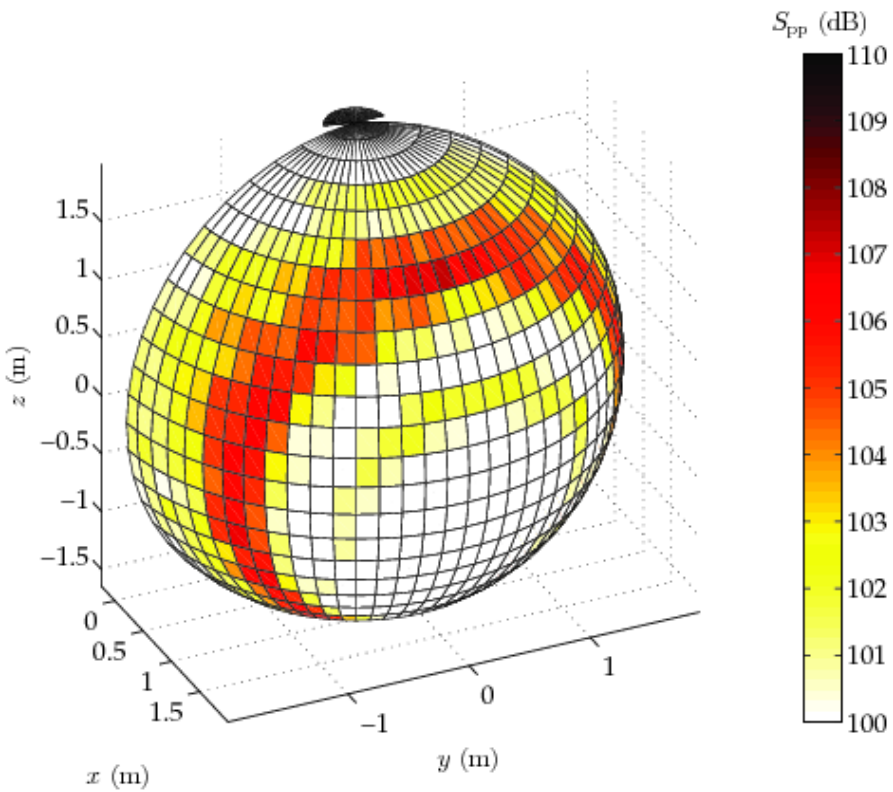


- Measurements with a fan derived from the LEAP-X
- Evidence on acoustic modes in the exhaust pipe but also :
 - In the vicinity of the fan
 - In the torque signal
 - In the axial force signal
 - In the gauges signals
- The mode 14 Hz is finally the stronger precursors found before the onset of stall.





Examples of measurements

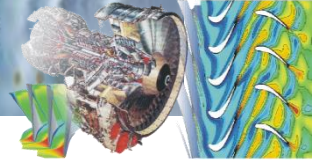


Sound Directivity

Highlight of frequency-chosen acoustic mode that propagates upstream of the fan

Fluids / Structure interactions measurements

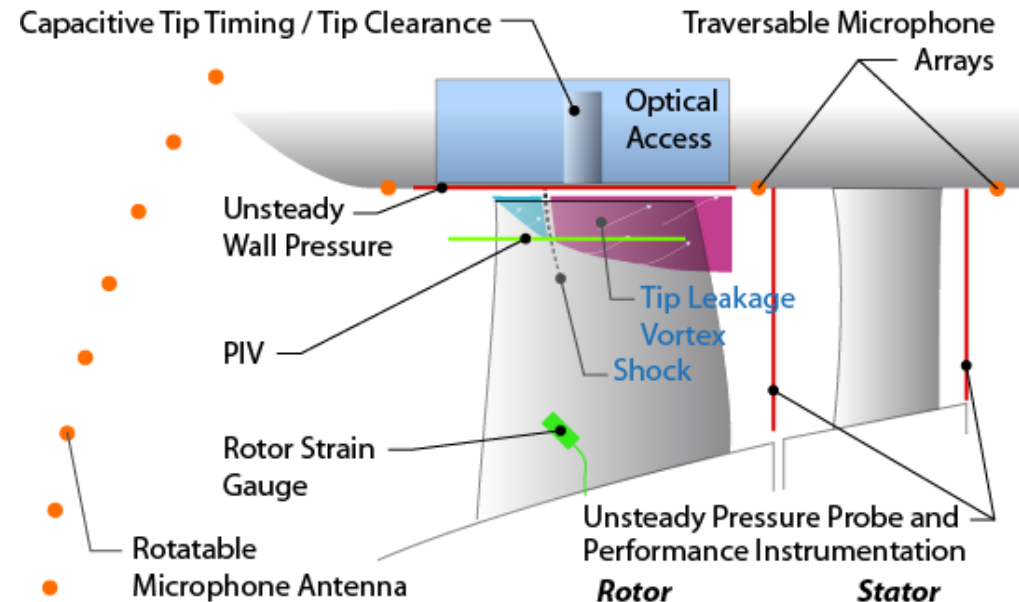
Comparison of structural and aerodynamic disturbances for 105% speedline; steady frame of reference.

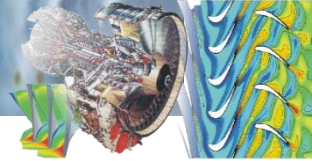


Summary

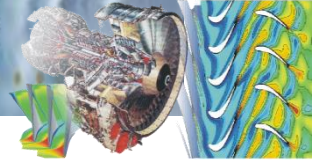
- Project PHARE-2 based on the fan studies, associated with the test rig ECL-B3
- First measurement campaign achieved with the version 0 derived from the LEAP
- Importance of the characterisation of the acoustic modes
- European Project ENOVAL – second campaign with a UHBR fan designed by SAE.
- Open test case ECL5 (to be presented next September: ISUAAAT15-071)
- European Thematic project
- Test rig for new/advanced acquisition methodologies (collaborations with VKI, Limmat Sci,...)

- Thanks the sponsors !
 - Safran Aircraft Engines
 - ANR
 - ECL
 - Institut Carnot Ingénierie @Lyon
 - European Project ENOVAL

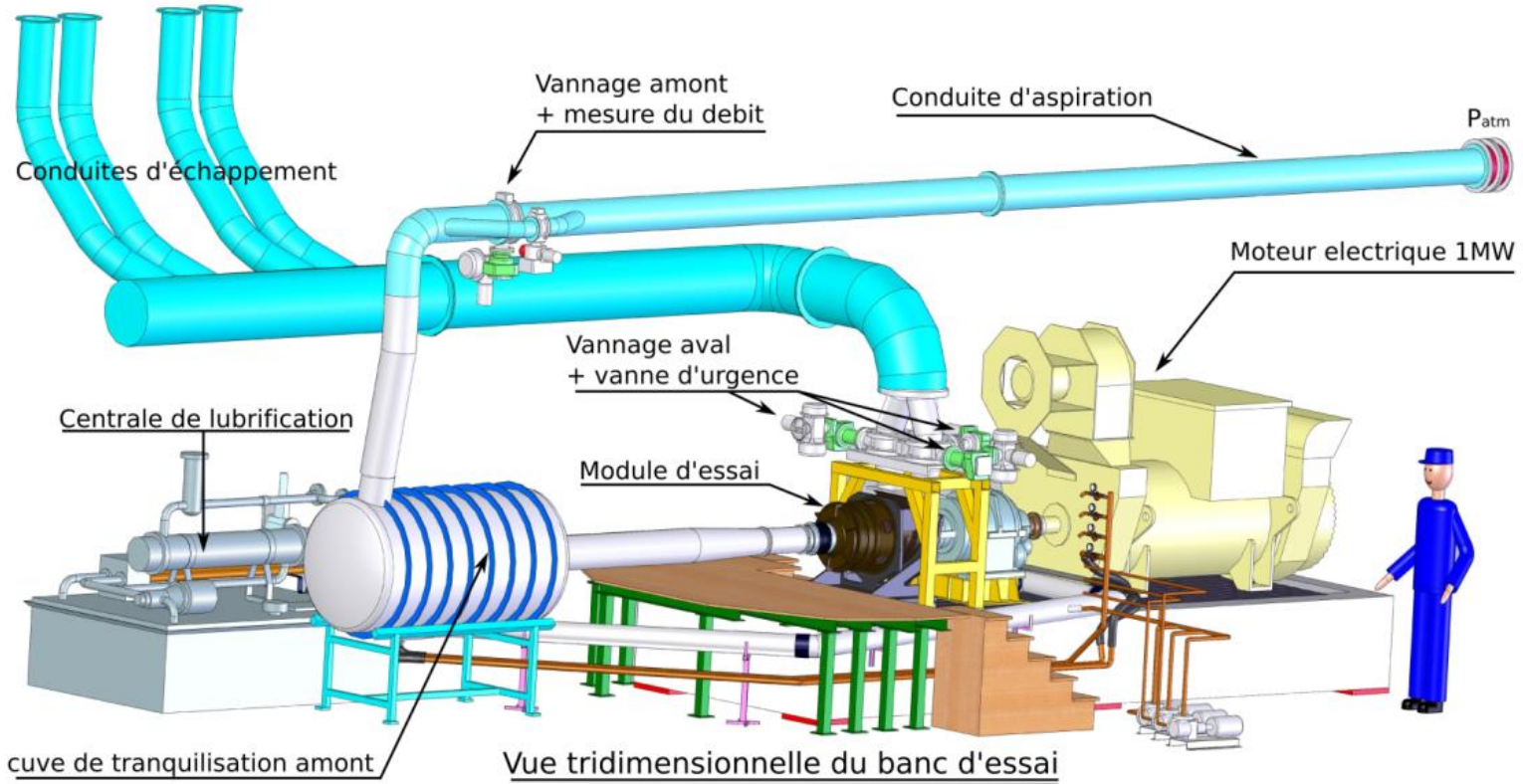
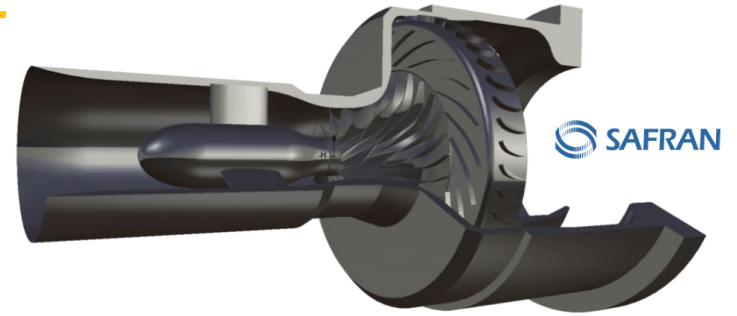


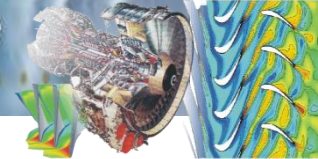


Back up

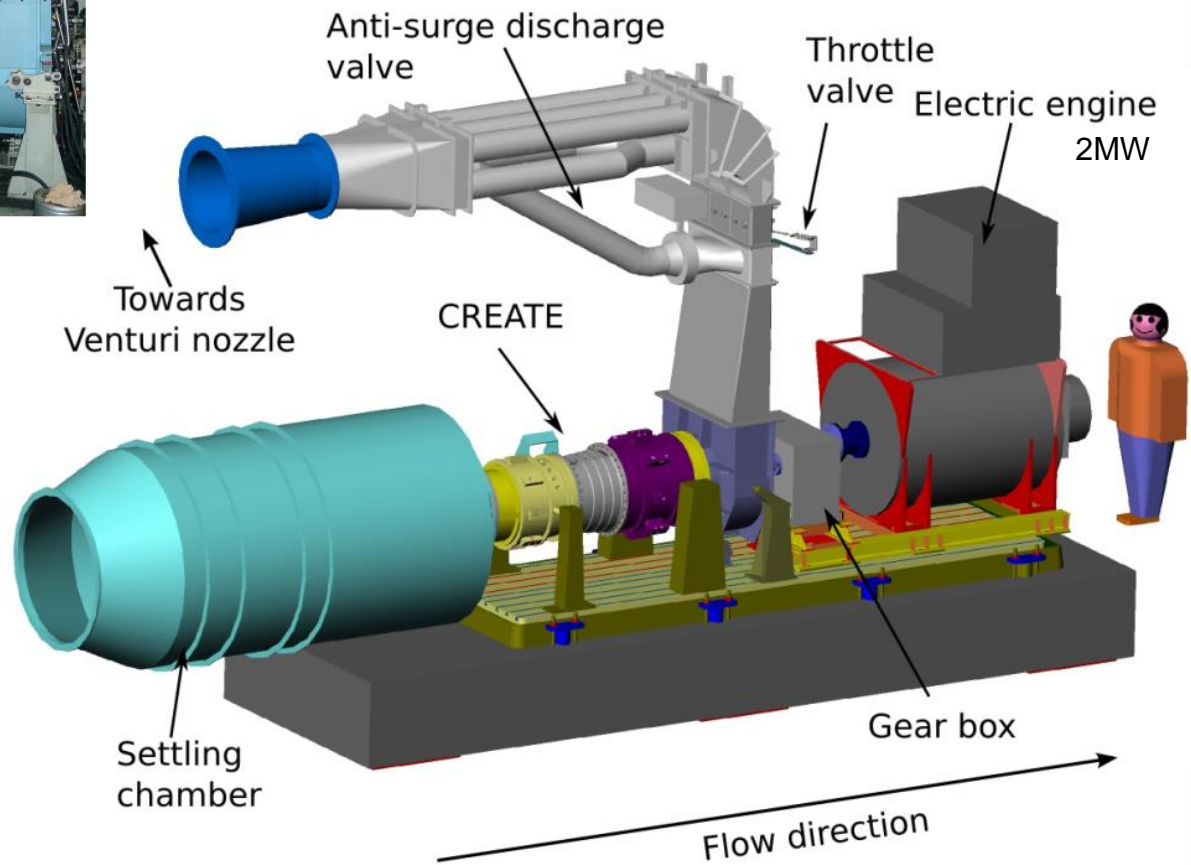
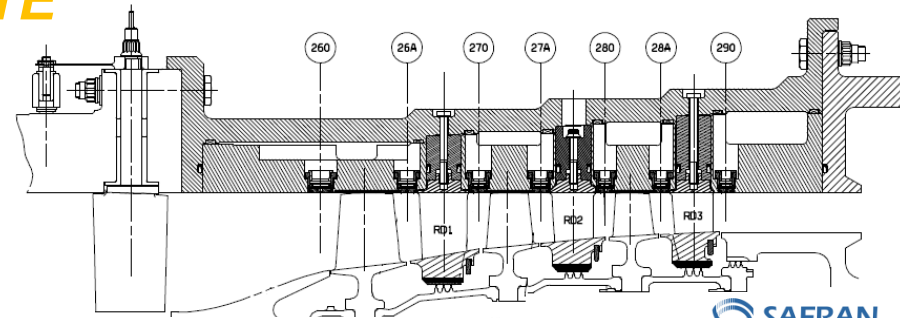


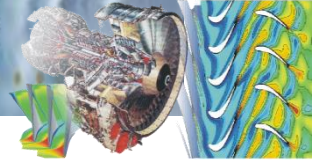
ECL-B1 / Centrifugal compressor PI-9 / TURBOCEL





ECL-B2 / Multistage axial compressor CREATE





Longeur Accordable 8m x D30cm

