CHALMERS

EXPERIMENTAL AERODYNAMIC INVESTIGATION OF POWERED NACELLES FOR HIGH BYPASS TURBOFAN ENGINES

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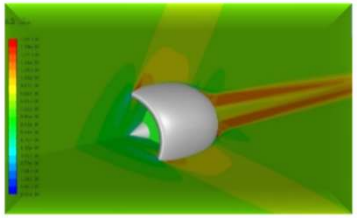
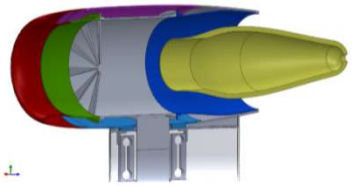
SUSTAINABLE AEROSPACE INNOVATION IN A GLOBALISED WORLD
FT2019

ITAP- Integrated Turbofan Airframe Performance

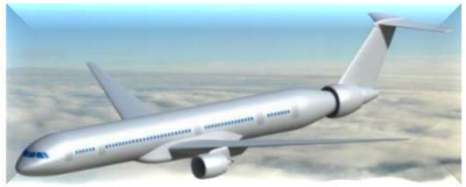
- NFFP7 Innovair Project
- Duration: 4 years
- Chalmers – GKN

Standalone nacelle design and experiments





Innovative Integration – BLI ingestion



Conventional advanced integrated configurations :

- Ultra high bypass turbofans
- Ultrashort and thin Nacelles

TURBOFAN NACELLE DESIGN – Class Shape Transformation (CST) Method

$$\xi(\psi) = \mathrm{S}(\psi)C(\psi) + \psi\Delta\xi_{te} \;\rightarrow\; \xi = y/c \qquad \psi = x/c$$

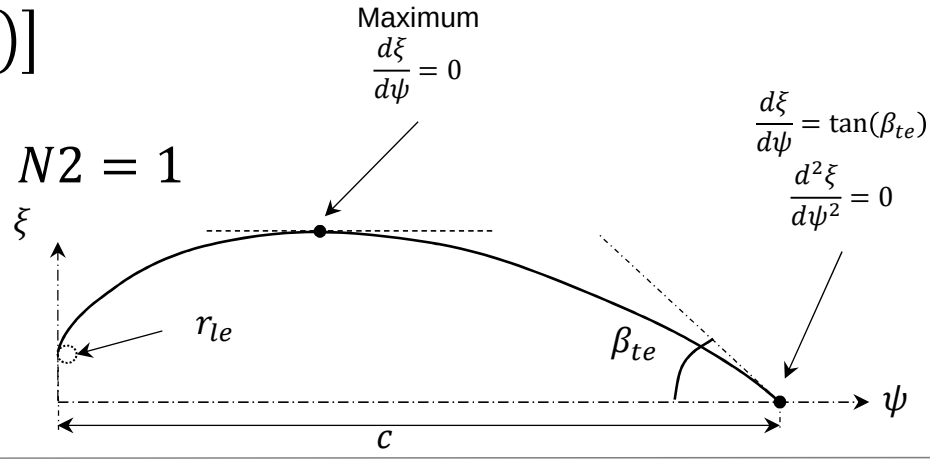
$$\mathrm{BP}(\psi) = \sum_{i=0}^{n}\left[K_{i,n}\cdot\left(\psi^{i}(1-\psi)^{n-1}\right)\right] \rightarrow K_{i,n} = \frac{n!}{i!\,(n-1)!}$$

$$\mathrm{S}(\psi) = \sum_{i=0}^{n}\left[bp_i\cdot K_{i,n}\cdot\left(\psi^{i}(1-\psi)^{n-1}\right)\right]$$

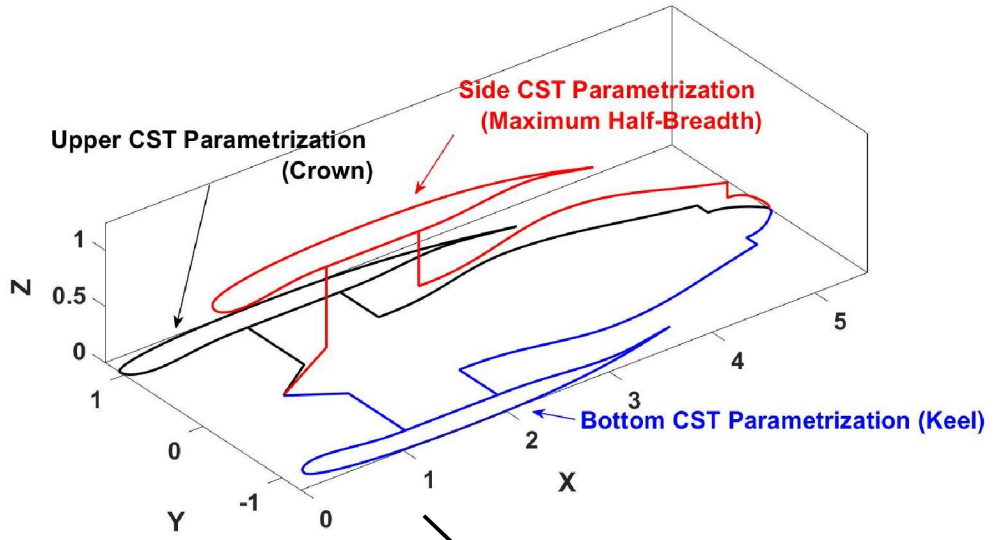
$$C(\psi) = (\psi^{N1}(1-\psi)^{N2}) \rightarrow N1 = 0.5 \;\; N2 = 1$$

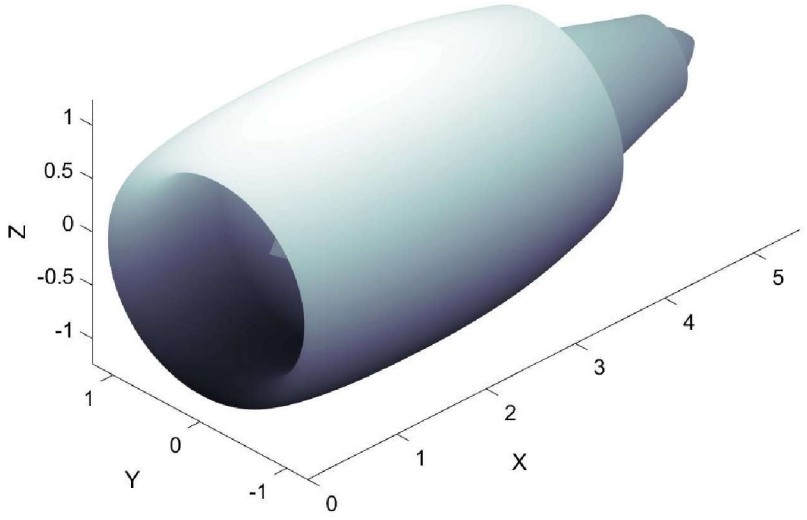
$$bp_0 = \sqrt{\frac{2r_{le}}{c}}$$

$$bp_n = \tan(\beta_{te}) + \frac{\Delta\xi_{te}}{c}$$



TURBOFAN NACELLE DESIGN – 3D GEOMETRY GENERATION



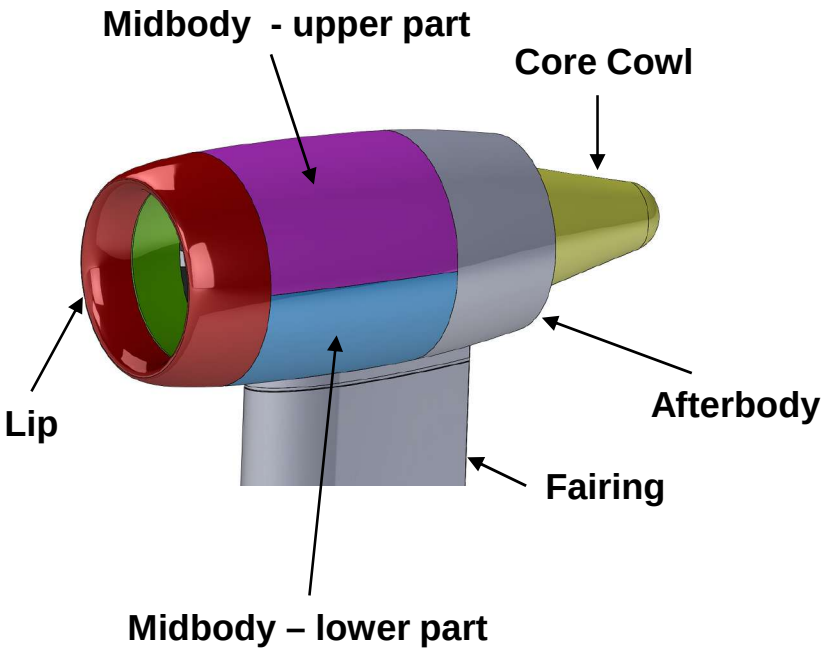


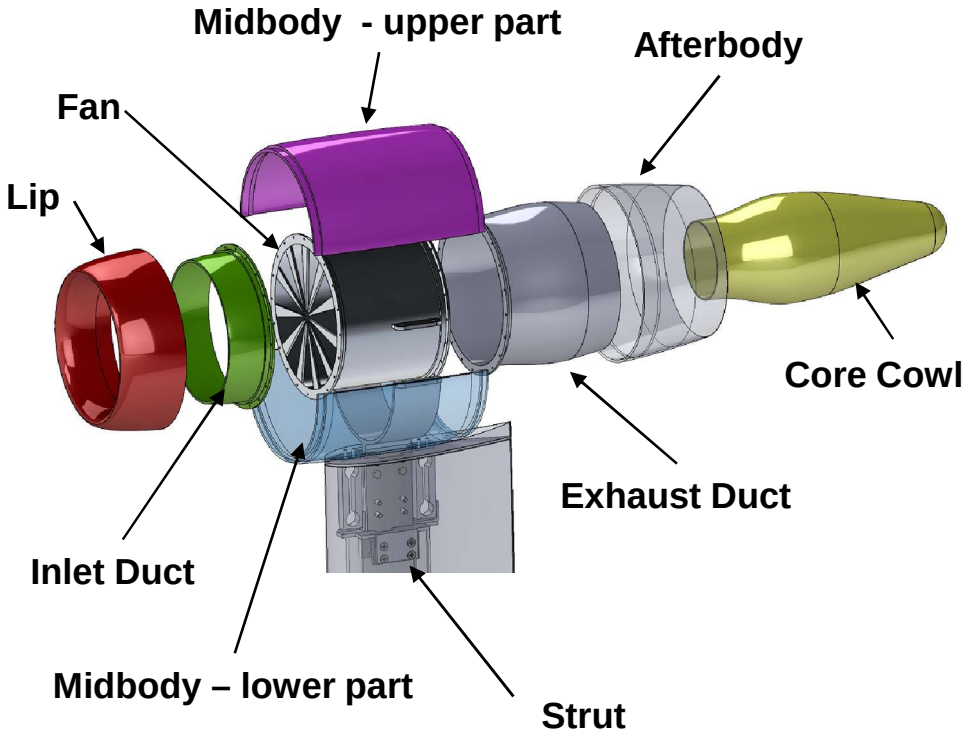
Sinusoidal interpolations
tangentially and axially

Electric Ducted Fan (EDF) and controller (ESC)

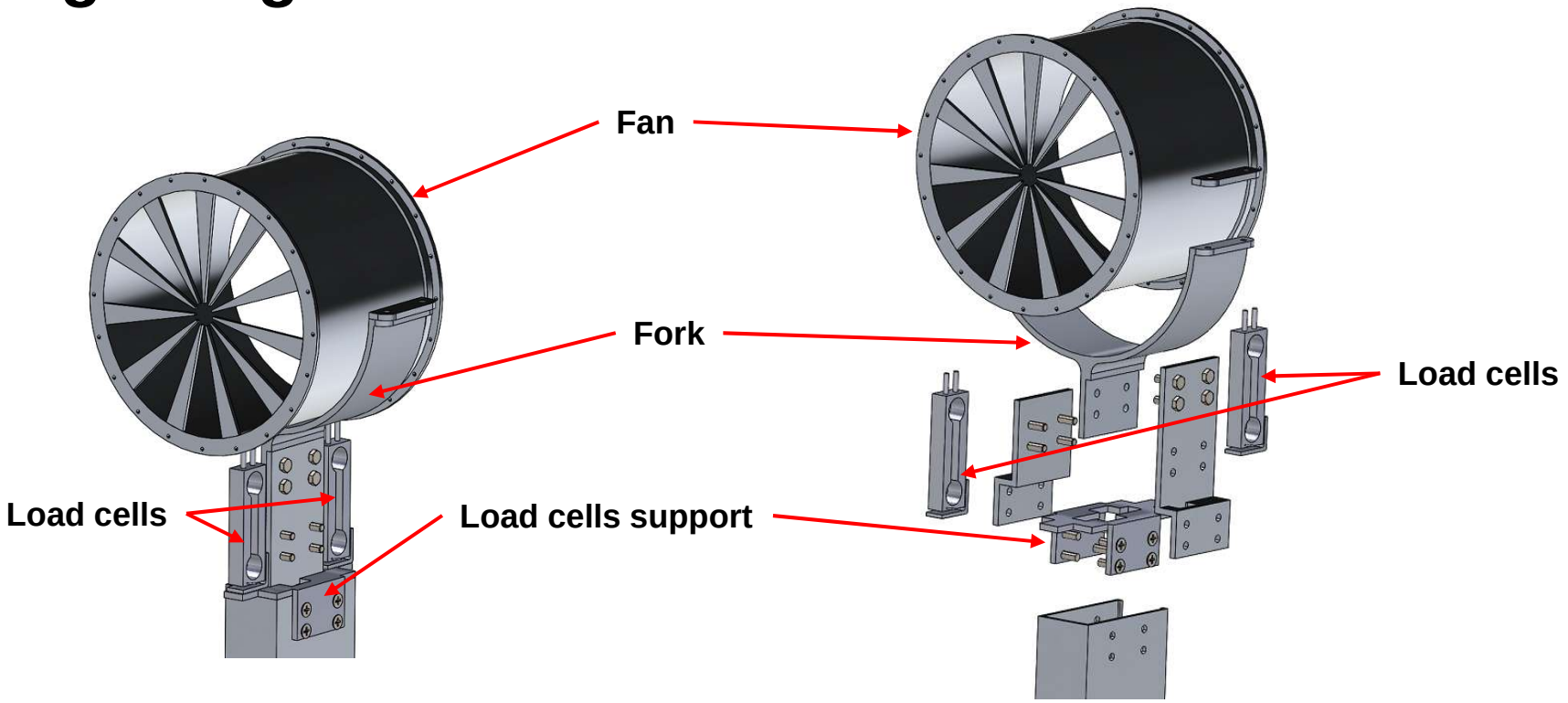
Fan diameter: 195 mm
Fan Speed: 12.000-14.000 rpm
Power: 9,8 kW-15,6 kW
Thrust: 215-250 N

Rig design - CAD

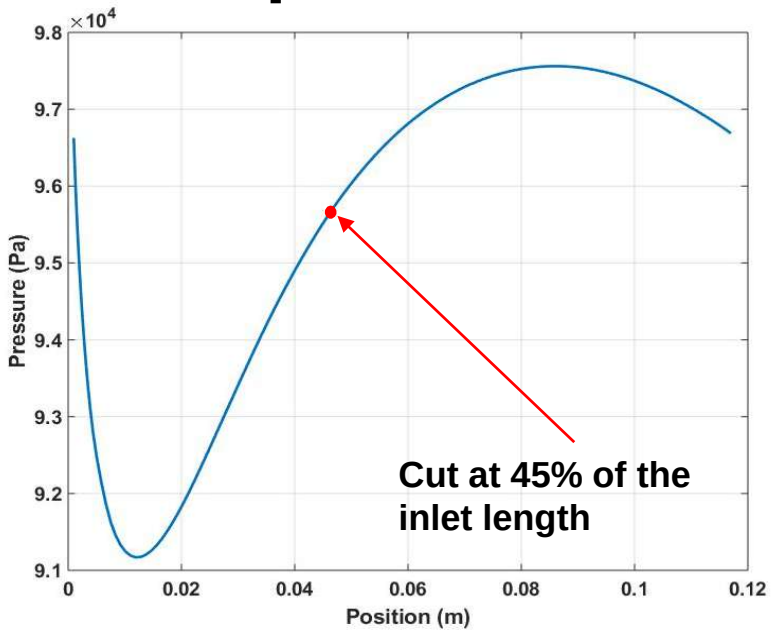




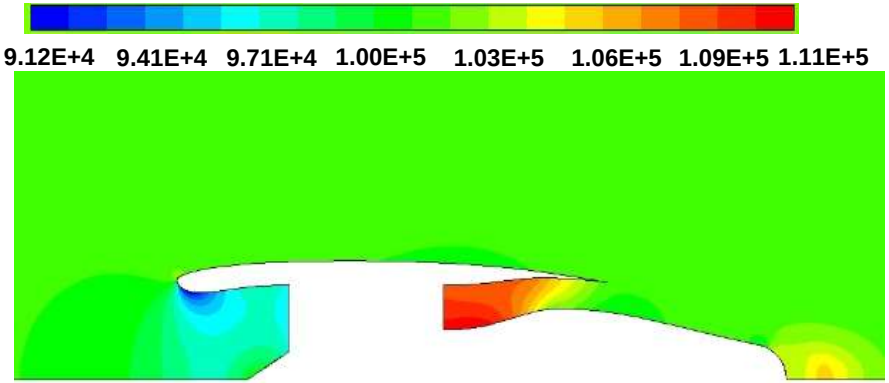
Rig design - Structure



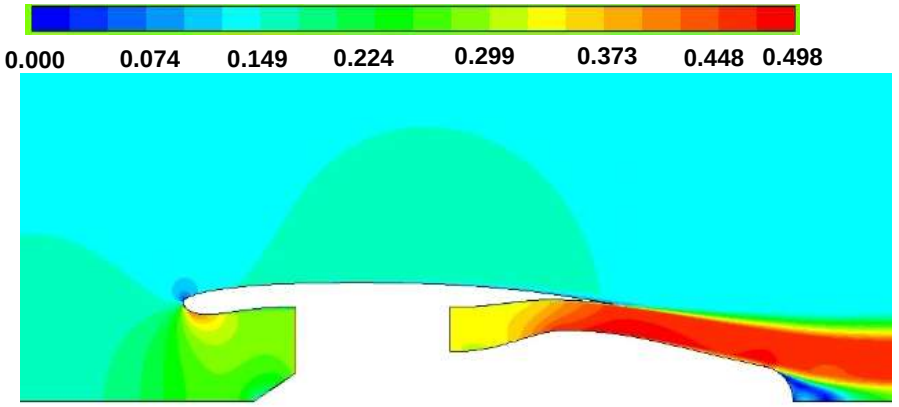
Inlet split



Wind speed = 50 m/s
Fan Mach Number = 0.29

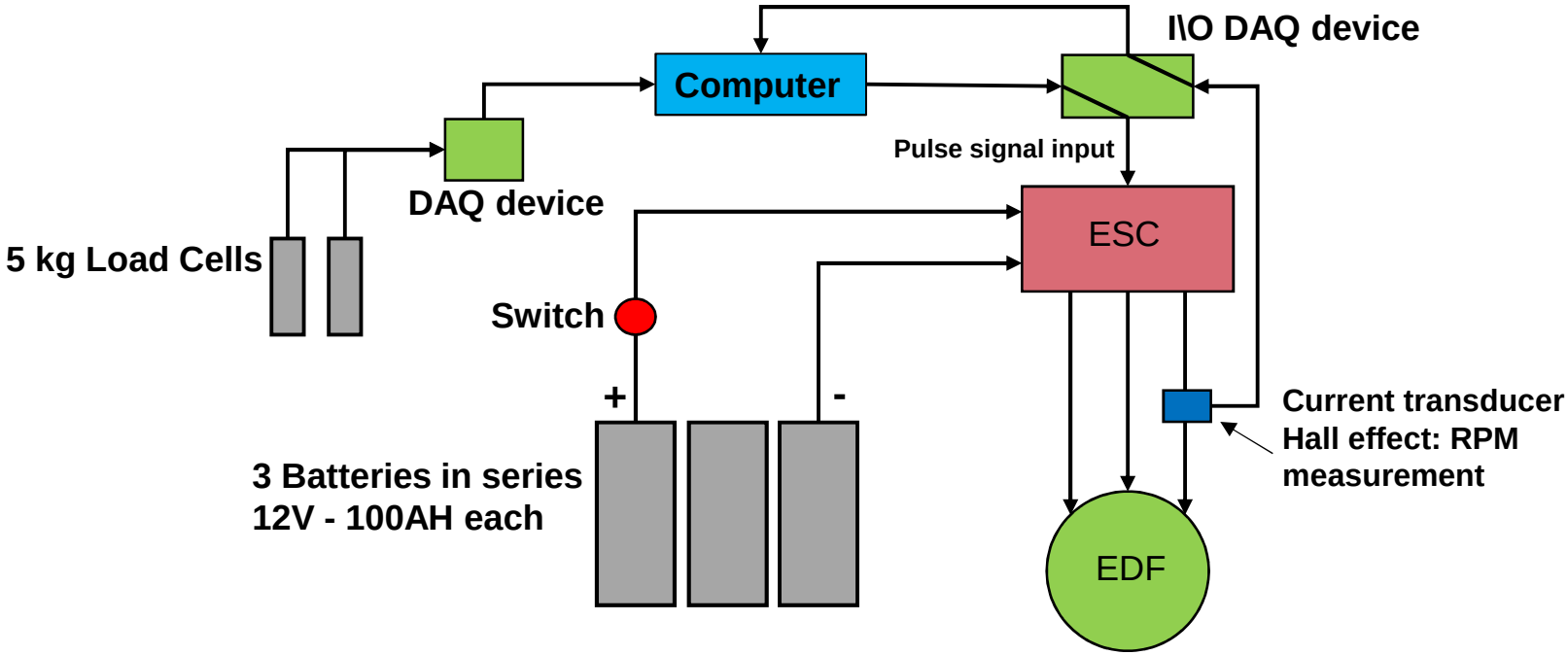


Contours of Static Pressure



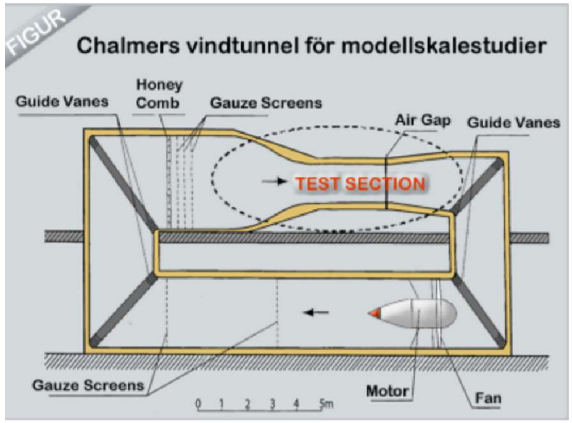
Contours of Mach Number

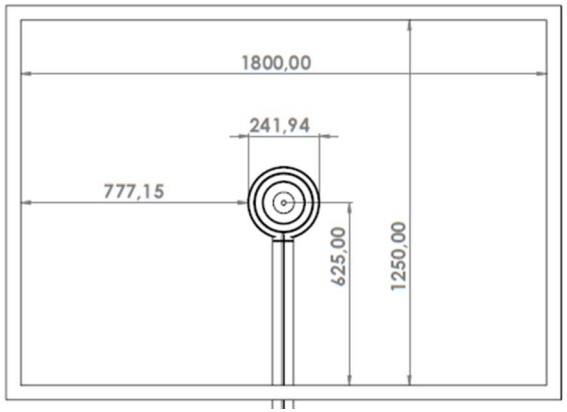
Simplified wiring diagram

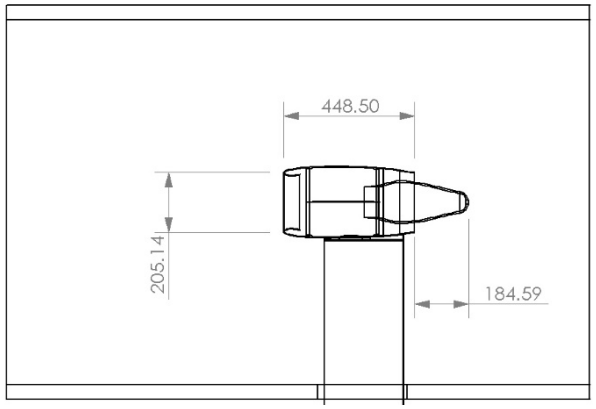


Chalmers large-scale low-speed wind tunnel

- **Maximum Velocity: 60 m/s**
- **Test Section Area: 1.80x1.25 m²**
- **Test Section Length: 3 m**
- **Main Fan power: 170kW**

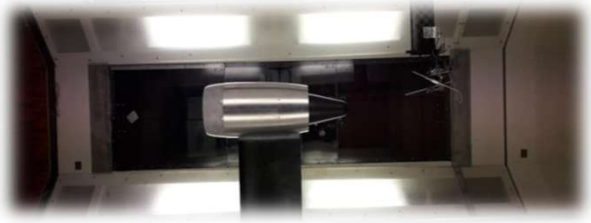


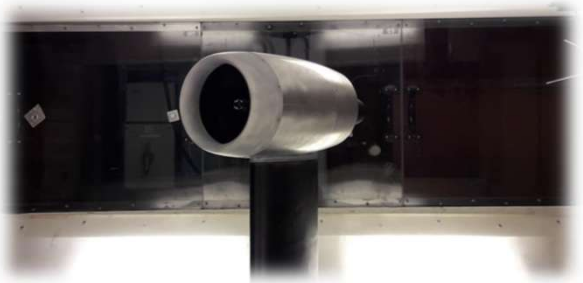




Rig assembly

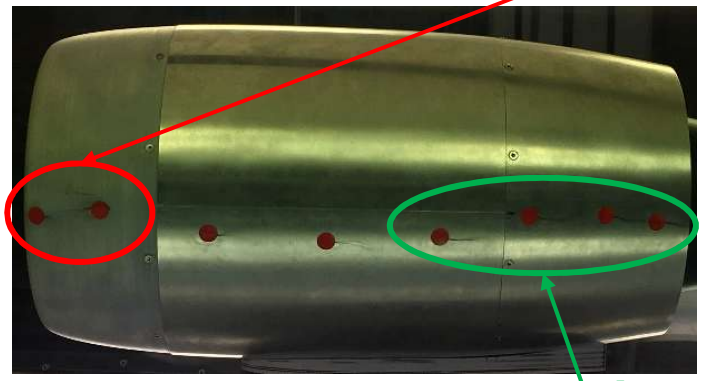
Rig mounted in the wind tunnel

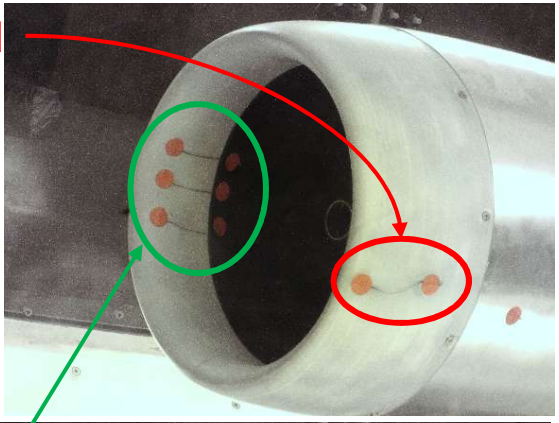




Flow visualization

Separated



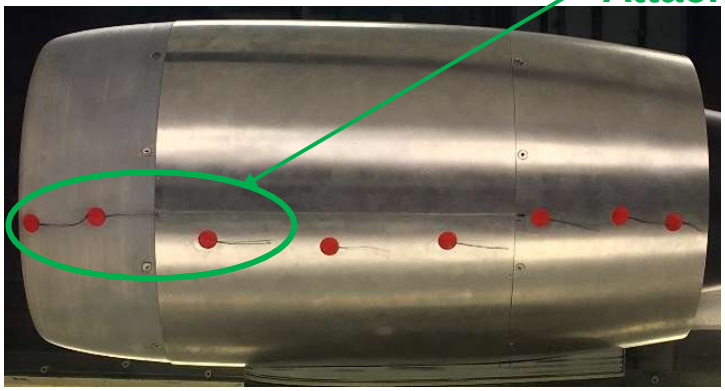


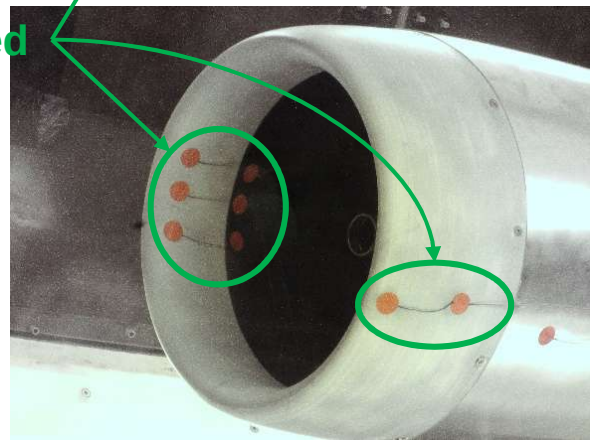
Angle of attack = 10 deg

Wind speed = 30 m/s

Fan Speed = 0 RPM

Attached





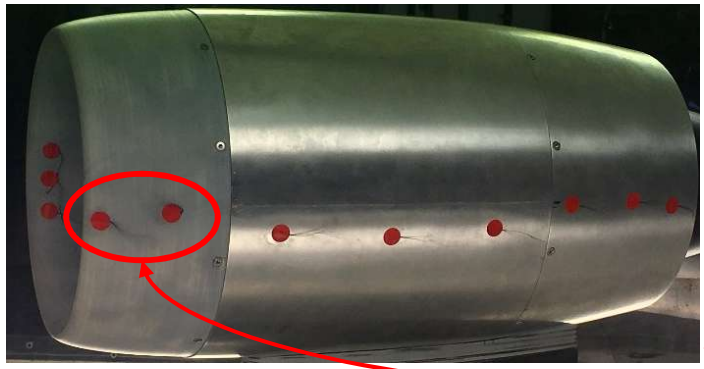
Angle of attack = 10 deg

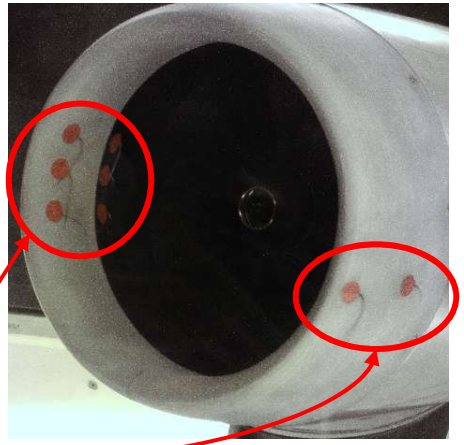
Wind speed = 30 m/s

Fan Speed = 7750 RPM

Figures from leeward side

Flow visualization





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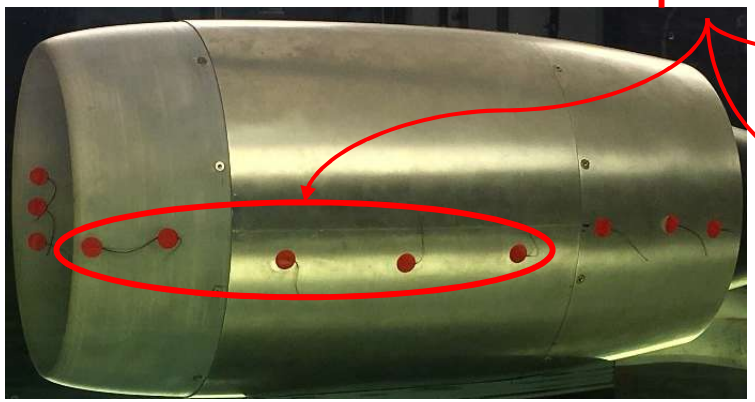

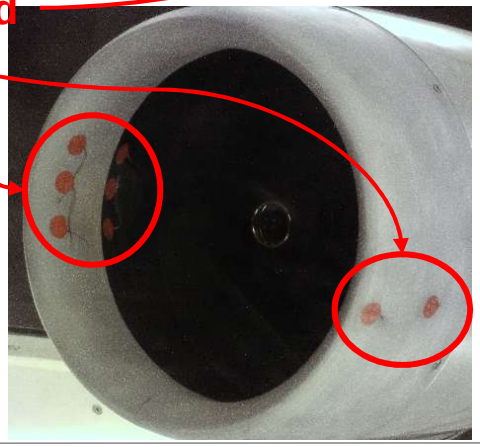

Angle of attack =25 deg

Wind tunnel speed = 30 m/s

Fan Speed = 0 RPM

Angle of attack =25 deg

Wind tunnel speed = 30 m/s

Fan Speed = 7870 RPM

Figures from leeward side

Future work

- Drag from load cells and from wake surveys
- Thrust measurements
- Particle Image Velocimetry - PIV
- Pressure taps in different circumferential Nacelle positions
- Study of different intake geometries – drooped inlet
- Validation of low speed CFD simulations.

THANKS FOR LISTENING!