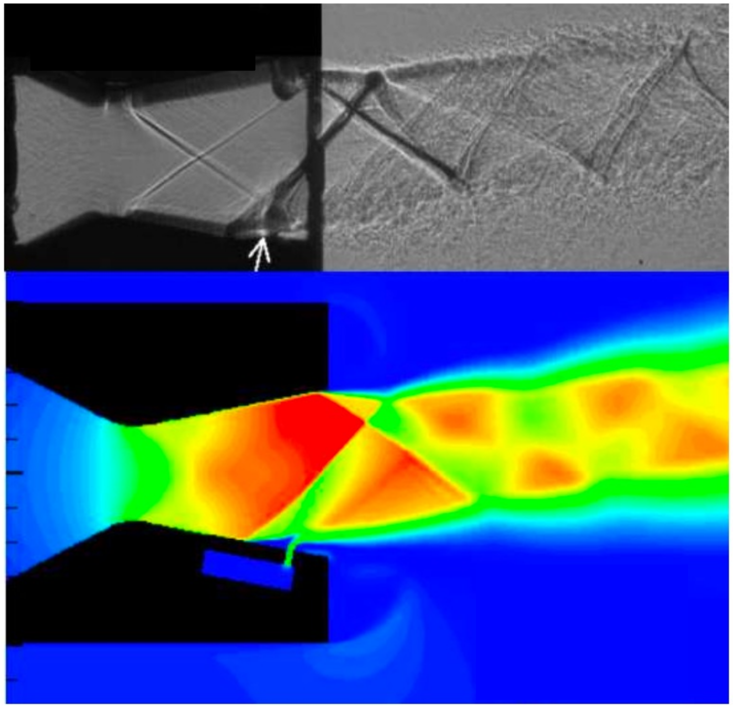
ESTACA / AAD (2023)

CFD Project

Numerical Simulations and Design of **Fluidic Thrust Vectoring (FTV)**



Numerical Simulation and Design of FTV

► Context and objectives

- The role of a Converging-Diverging (CD) Supersonic Nozzle is to generate thrust by expanding gases in a duct.

- Thrust Vectoring can enhance manoeuvrability by deviating the exhaust flow.

- Modern fighter jets rely on Mechanical Vectoring by changing the geometry of the nozzle.

- But those systems are heavy and require extra maintenance → promising solution: Fluidic Thrust Vectoring (FTV) based active flow control (AFC).

- **<u>Objective</u>: Design an efficient FTV for given specifications**

Final presentation (20 min.) ~mid-May

Part I **Validation** of the CFD tool Numerical results ⟷ Experimental data	Part II **Design** of nozzles with CFD tool

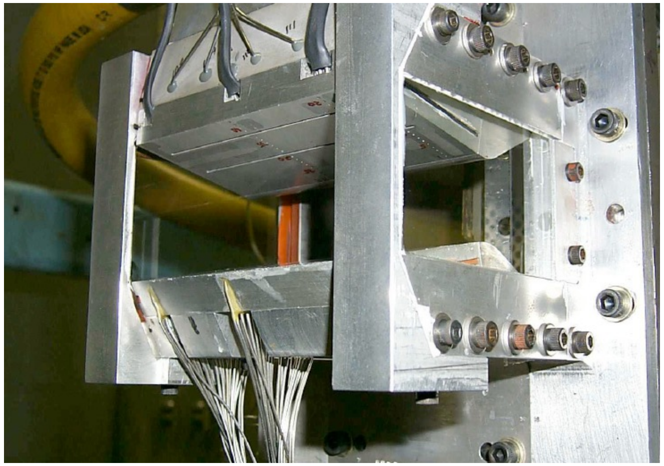
Mid-term presentation (20 min.) ~mid-March

Numerical Simulation and Design of FTV

► Part I (Validation)

- Validation of the CFD workflow on the nozzles of Waithe and Deere (2003)

$$\mathrm{NPR} = \frac{p_{t,p}}{p_a}$$



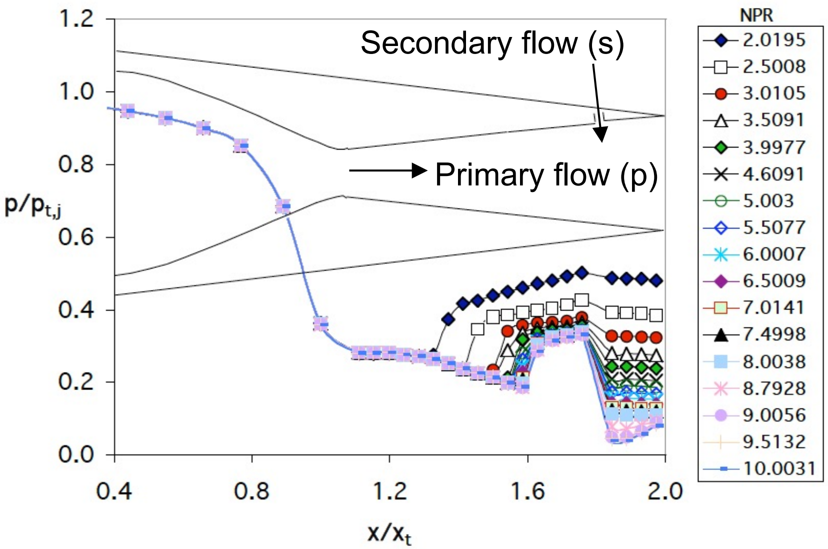


Figure 9. Centerline, upper surface, static pressures for configuration 1, SPR=0.7.

$$\mathrm{SPR} = \frac{p_{t,s}}{p_{t,p}}$$

- CFD workflow check:
  - ✓ Geometry
  - ✓ Mesh
  - ✓ Governing equations
  - ✓ Boundary conditions
  - ✓ Numerical schemes
  - ✓ Post-processing

Numerical Simulation and Design of FTV

► Part II (Design)

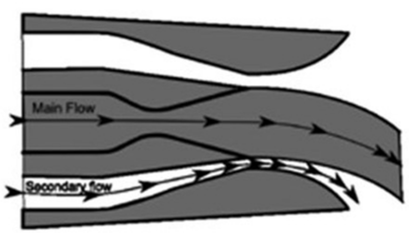
- Design a FTV nozzle to match the specifications and maximize the efficiency η (station 4 designates the entry of the nozzle).

M_∞	Z	Nozzle exit Mach number M_e	$\frac{p_{t,4}}{p_{t,\infty}}$	$\frac{T_{t,4}}{T_{t,\infty}}$	Thrust (Fx)	Fn/Fx
1,8	5 000 m	2,2	2	2,5	10 kN	20%

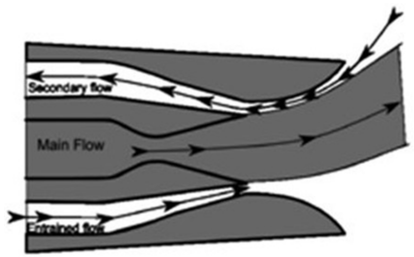
Primary flow deviation

$$\eta = \frac{\delta_p}{\frac{\mathrm{MFR}_s}{\mathrm{MFR}_{p+s}}}$$

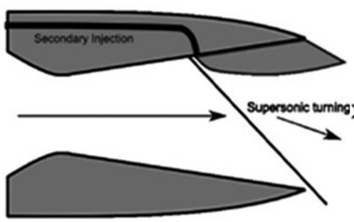
- Evaluate different options:



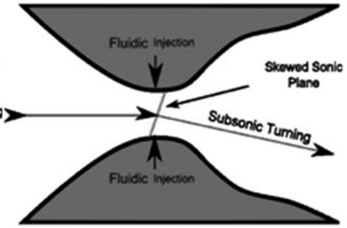
Coflow



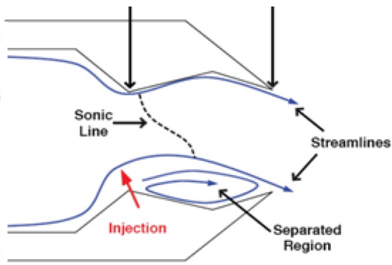
Counter-flow



Shock Vector Control (SVC)



Throat Shifting or Skewing (TS)



Dual Throat Nozzle (DTN) or Recessed Cavity Nozzle (RCN)

Numerical Simulation and Design of FTV

► Useful formulas

$$MFR = q_m = 0{,}04041 \frac{p_t A_t}{\sqrt{T_t}}$$

$$F_x = \big(\Phi(M_e) - \Phi(1)\big) \times p_t \times A_t \qquad \Phi(M) = \varpi(M) \times (1 + \gamma M^2) \times \Sigma(M)$$

$$\frac{A}{A_t} = \frac{1}{M}\left[\frac{2}{\gamma+1}\left(1 + \frac{\gamma-1}{2}M^2\right)\right]^{\frac{\gamma+1}{2(\gamma-1)}} = \Sigma(M)$$

$$\frac{p}{p_t} = \varpi(M) = \left(1 + \frac{\gamma-1}{2}M^2\right)^{\frac{-\gamma}{\gamma-1}}$$