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Guillermo Lopez Quesada, Ahmad Batikh, Stéphane Orioux, Nicolas
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Design and evaluation of pulsed jet actuators (PJAs) network for active flow control on NACA-4412 profile

Guillermo López Quesada

*Lucien Baldas, Stéphane Orioux, Ahmad Batikh, Nicolas Mazellier
GDR - Contrôle de Décollements*

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- Introduction
- Working principle of the fluidic oscillator
- Validation of numerical tools
- Design of PJAs for the NACA-4412
- Definition of the PJAs assembly
- Manufacturing of the PJAs assembly
- Analysis approach
- Results:
 - First prototype
 - Round splitter
- Conclusions and perspectives

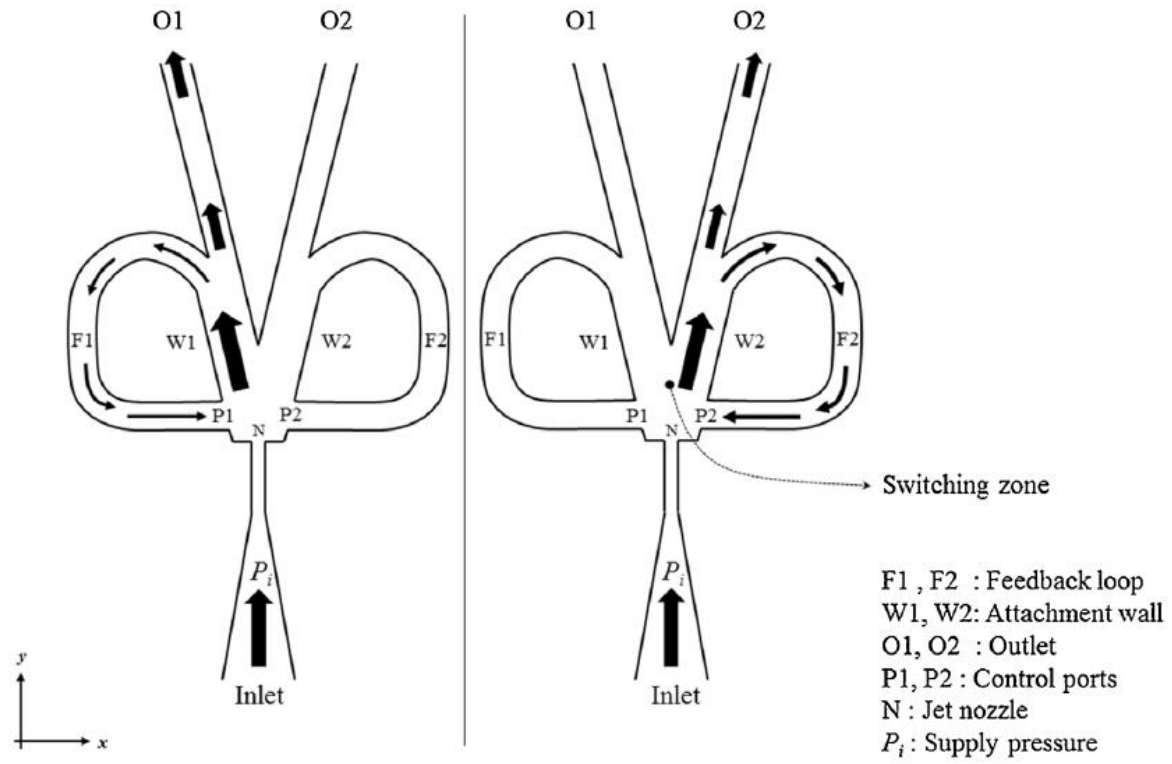
Pulsed jET actuatoRs for SEparation control of tURbulent flowS

- CleanSky 2 - RIA
 - JTI-CS2-2019-CFP10-AIR-02-77
 - Increasing the efficiency of pulsed jet actuators for flow separation control
- Consortium
 - University of Orleans (PRISME)
 - INSA Toulouse (ICA)
 - ENSAM Paris (Dynfluid)



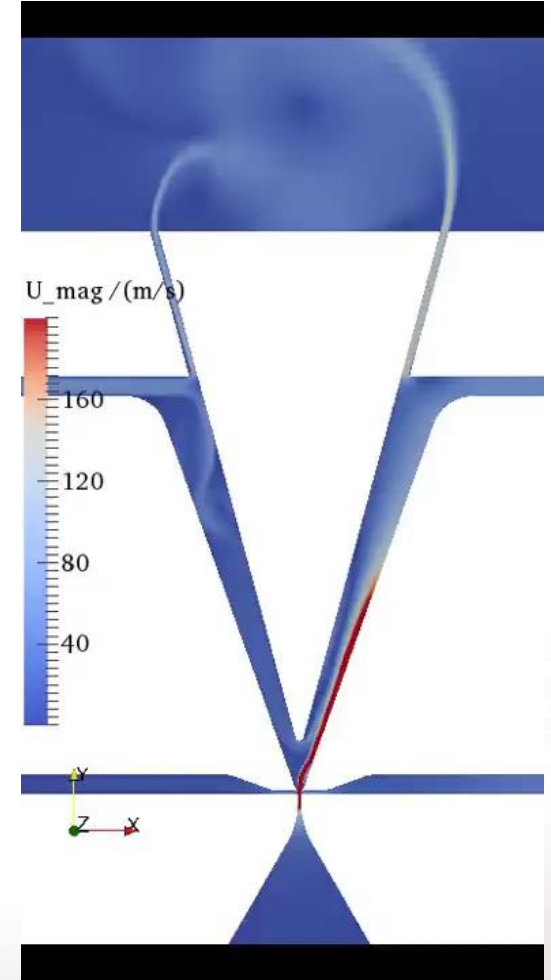
Working principle of fluidic oscillators

Jet oscillation mainly caused by the pressure wave propagation in the two feedback loops alternatively



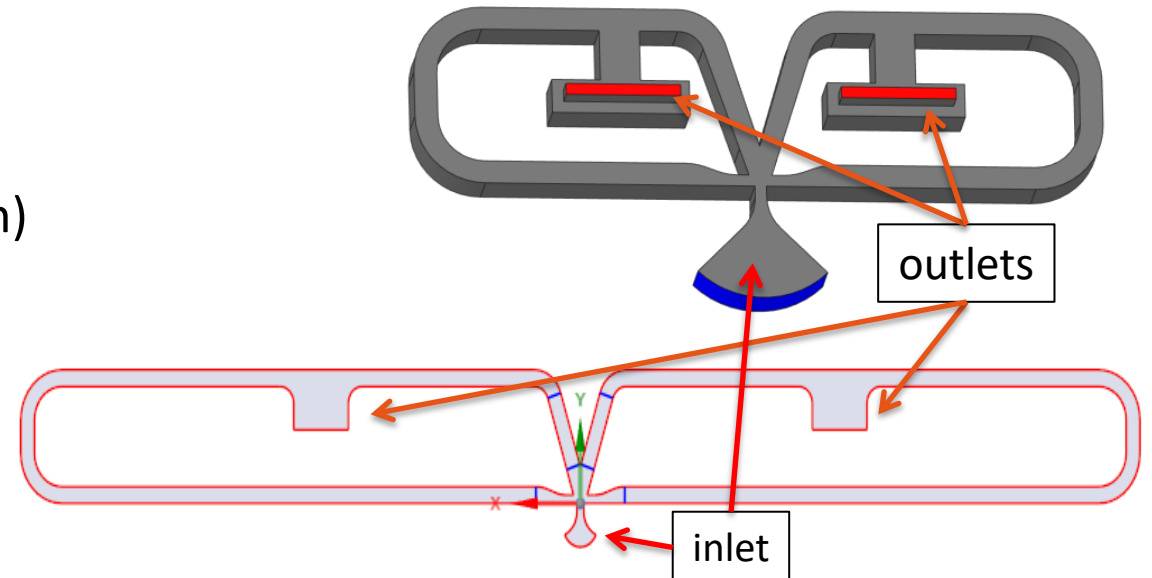
Pressure

Velocity



(Wang 2019)

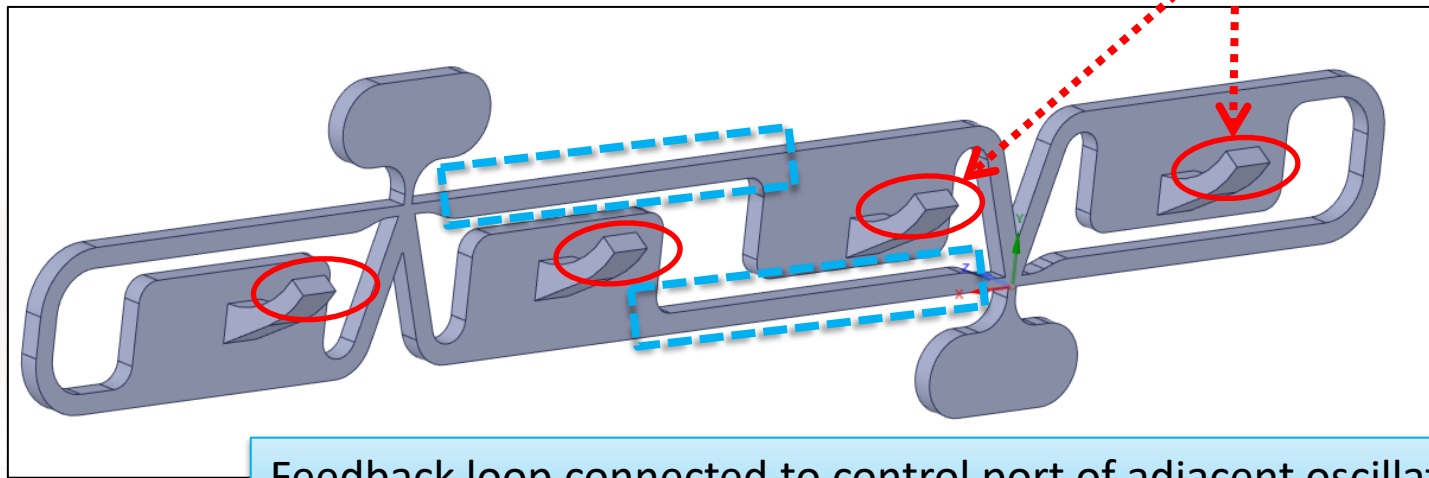
- CFD simulation with ANSYS FLUENT
 - K-epsilon turbulent model
- Sensitivity analysis 3D and 2D (18 different cases run)
 - Mesh quality (20k, 40k, 80k cells) $\leq 5\%$
 - Time step size (1e-5s, 5e-6, 1e-6, 1e-7) $\leq 2\%$
 - Discretization schemes (1st order, 2nd order) \approx same



3D and 2D simulations performed validated with hot wire anemometer

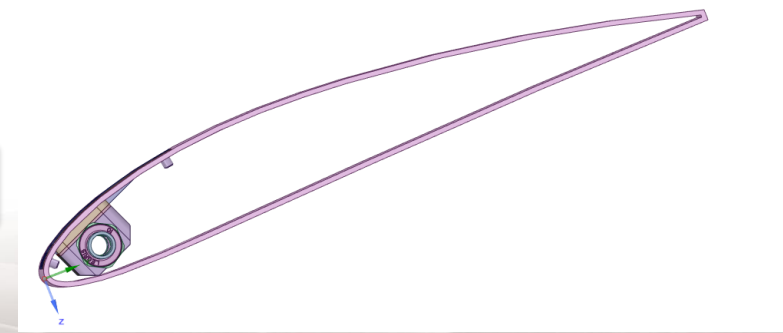
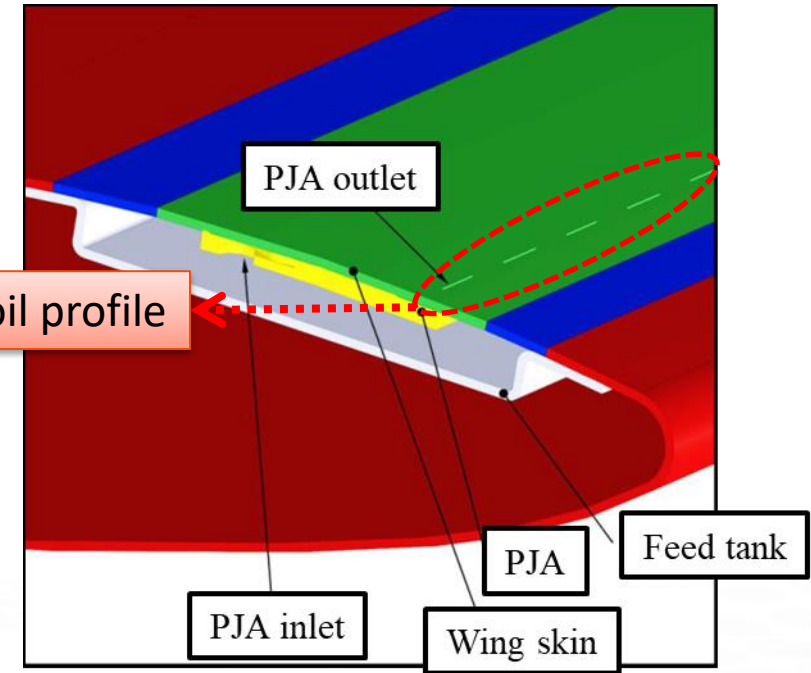
$F=1416$ Hz
 $V=20-120$ m/s at $P_i=3$ bar

- Adaptation of the PJAs for the implementation on the airfoil
 - Direction of the outlet
 - Synchronisation
 - Dimensional constraints (few centimeters)

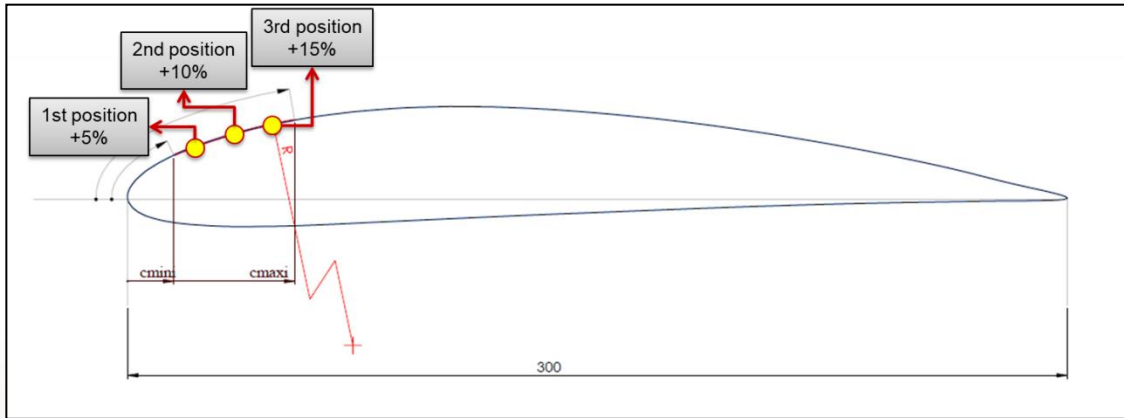


Feedback loop connected to control port of adjacent oscillator

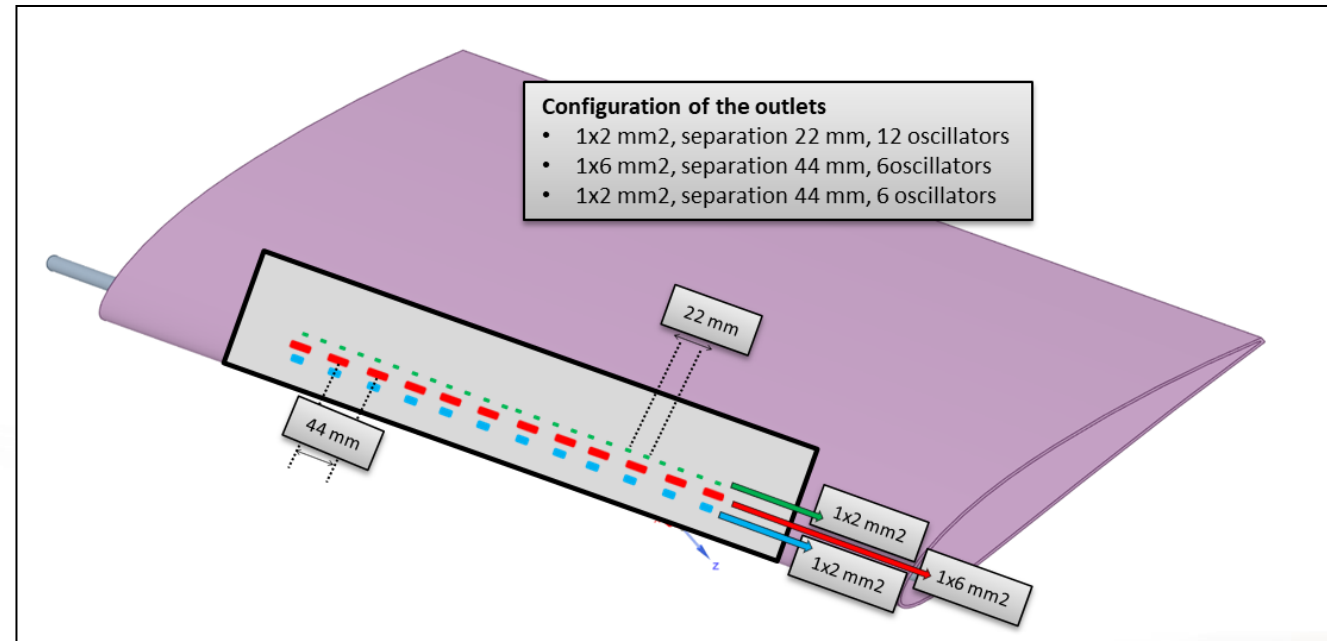
Outlets tangential to the airfoil profile



3 positions to be tested

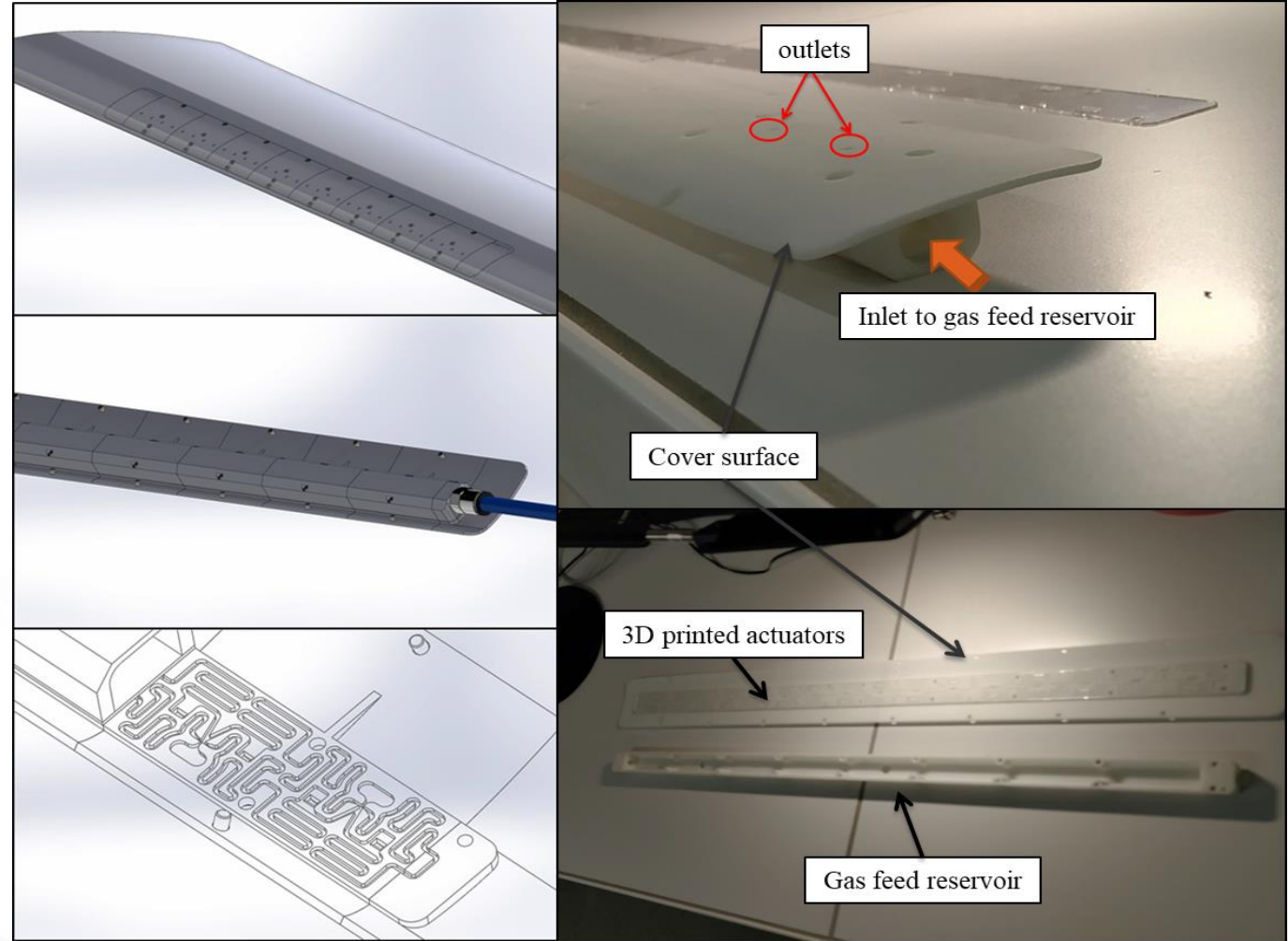


3 different aspect ratios-separations



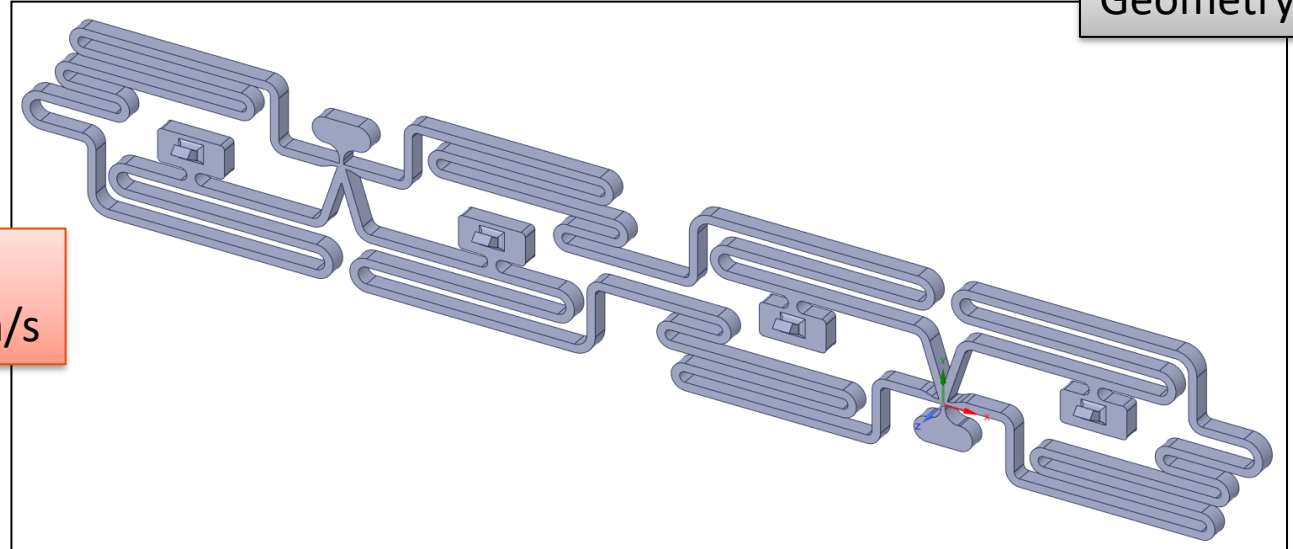
Manufacturing: 3D printing in one piece

- Minimum number of connections
- Profile smooth and perfectly adapted to the airfoil
- Outlet channels tangential to the profile
- Cost effective solution
- **A different actuator assembly for each configuration**



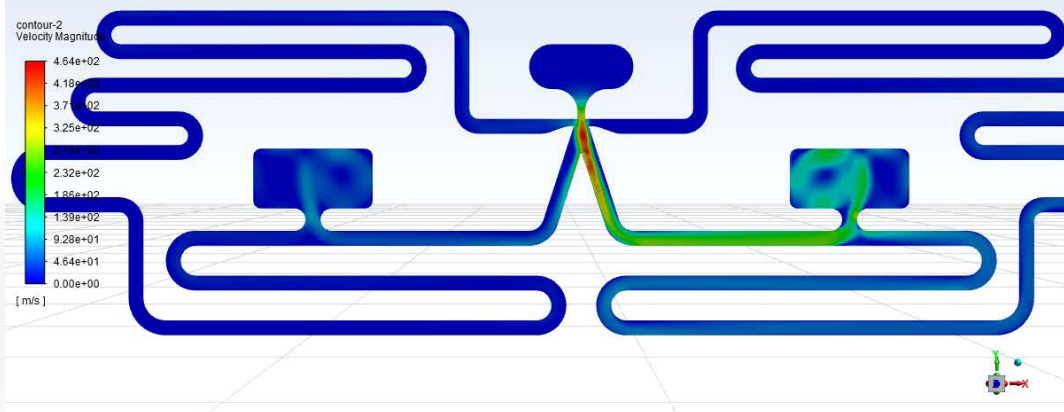
- First prototype:
 - Feedback loop length ≈ 190 mm
 - Feedback loop width ≈ 1 mm
 - Depth ≈ 2 mm

Geometry

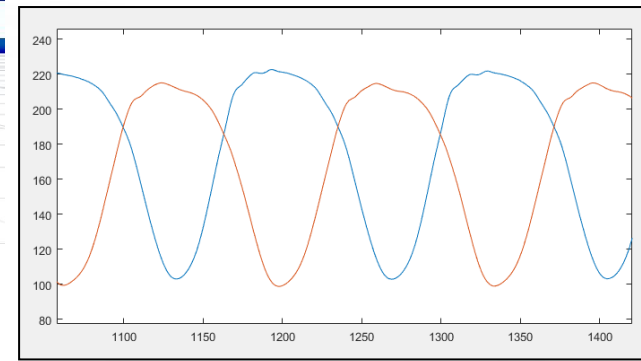


CFD Frequency ≈ 743 Hz
 Vel. Amplitude ≈ 100 -220 m/s

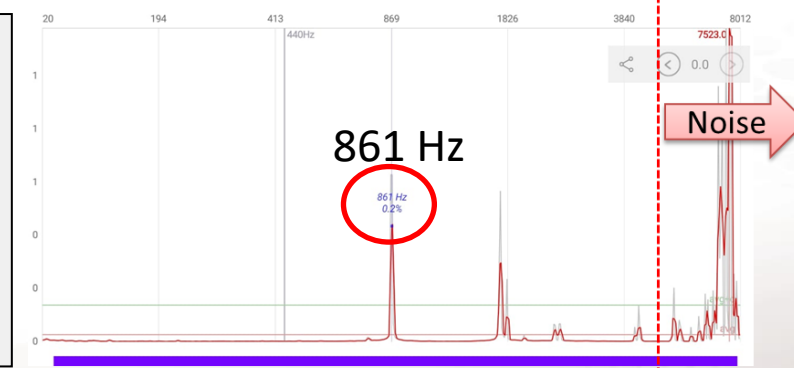
Velocity fields (CFD)



JET DOES NOT COMPLETELY SWITCH



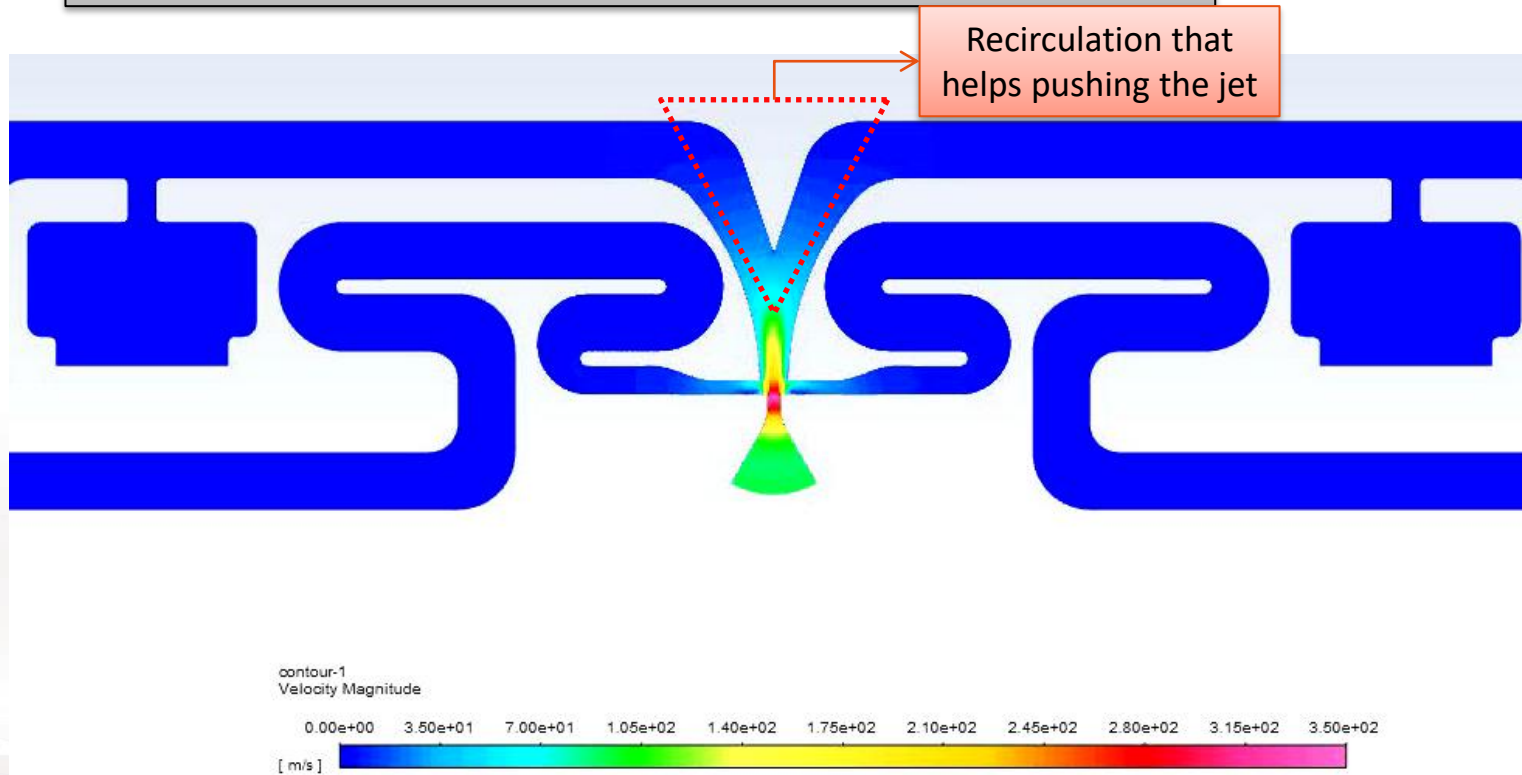
Avg. Velocity outlets (CFD)



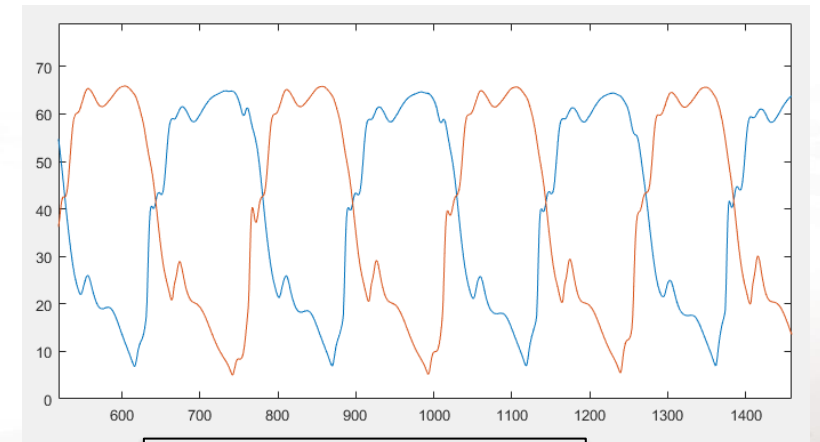
Measured frequency spectrum

- Modifications of the feedback loop:
 - Increase of the width
- Modifications on splitter:
 - Width of the splitter
 - Radius of the splitter corner
 - Angle of the splitter walls

- Rounded walls to induce smooth attachment
- Increased distance from inlet to splitter
- Increased width of the channels



- Model with round splitter:
 - Feedback loop length ≈ 137 mm
 - Feedback loop width ≈ 2 mm
 - 2D



Avg. Velocity outlets (CFD)

- **Conclusions:**

- The design of a PJAs assembly has been proposed and adapted to the constraints of a NACA-4412 profile
- The numerical tools used for the design of the PJAs has been verified and a sensitivity analysis has been done
- A preliminary prototype was fabricated for its implementation in the wing
- A new design with round splitter walls has been proposed to improve the switching of the jet

- **Perspectives:**

- 3D validation of model
- Fabrication and characterization (hot wire anemometer) of the new prototypes with round splitter walls
- Implementation and testing of the PJAs in the airfoil
- PJAs with different phases and/or multi-frequency

