

Conférence aérodynamique



I – Présentation générale et problématiques

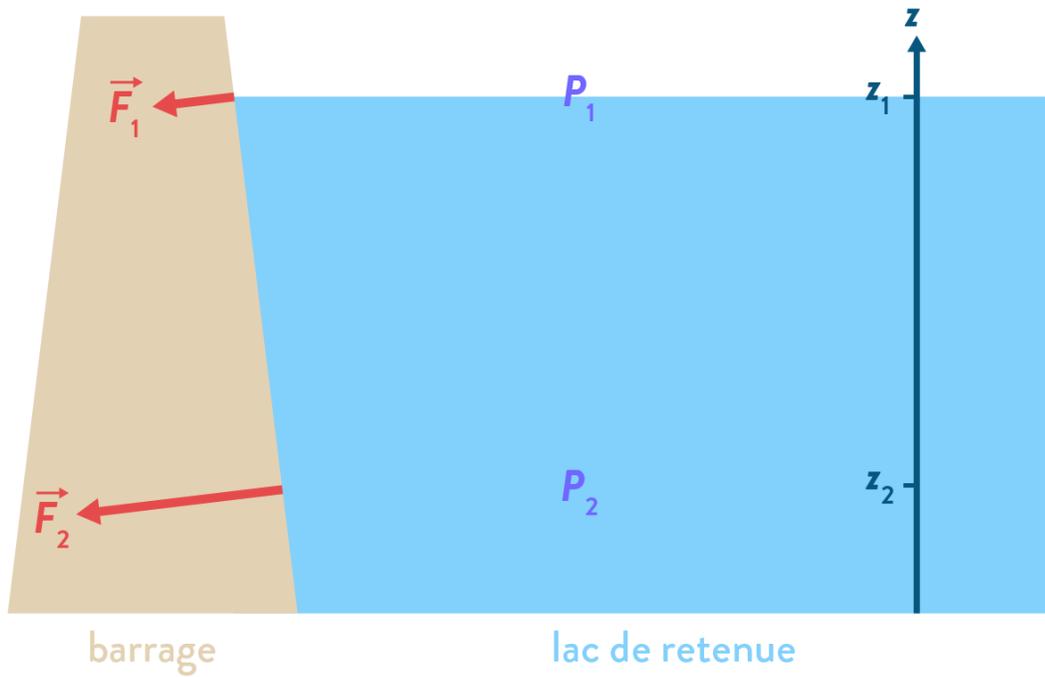
II – Les bases en turbulence

III – Les moyens d'essais

IV – La CFD (Computational Fluid Dynamics)

V – Application à nos chers simulateurs





Statique des fluides

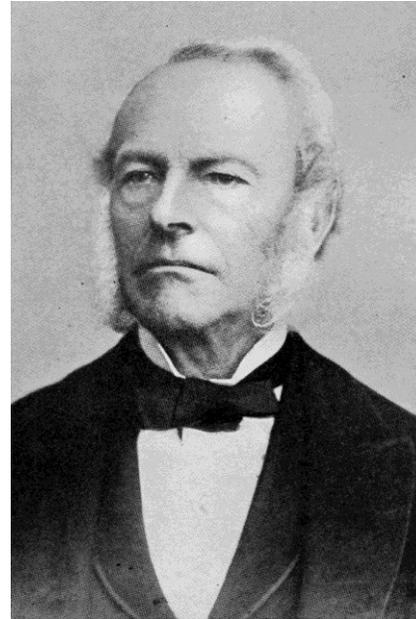
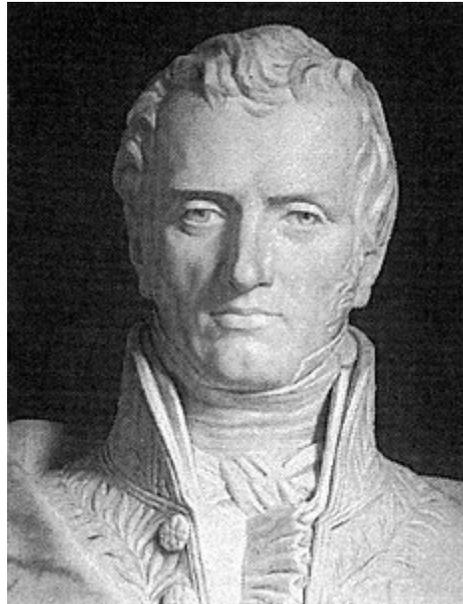


Dynamique des fluides



Leonhard Euler

Henri Navier



Gabriel Stokes

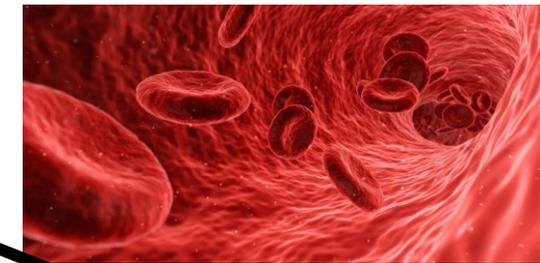
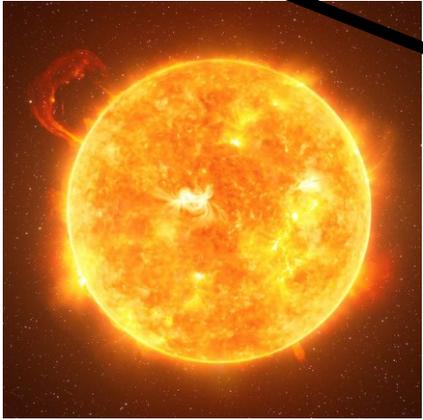
années	1700	1800	1900	2000
			Couette	
	d'Alembert		Reynolds	Blasius
	Pitot		Stokes	
	Bernoulli		von Karman	
			Prandtl	
		Navier	Joukovsky	
supersonique			Hugoniot	
			Mach	
			Rankine	
Diphasique milieux poreux		Darcy	Weber	
mathématiques	Lagrange	Riemann	Orr	Arnold
	Euler	Cauchy		
instabilités turbulence			Kelvin	
			Rayleigh	
			Helmholtz	Taylor
				Kolmogorov
microscopique et changement d'échelle			Knudsen	
			Boltzmann	
				Enskog
				Chapman



A quoi ça s'applique ?

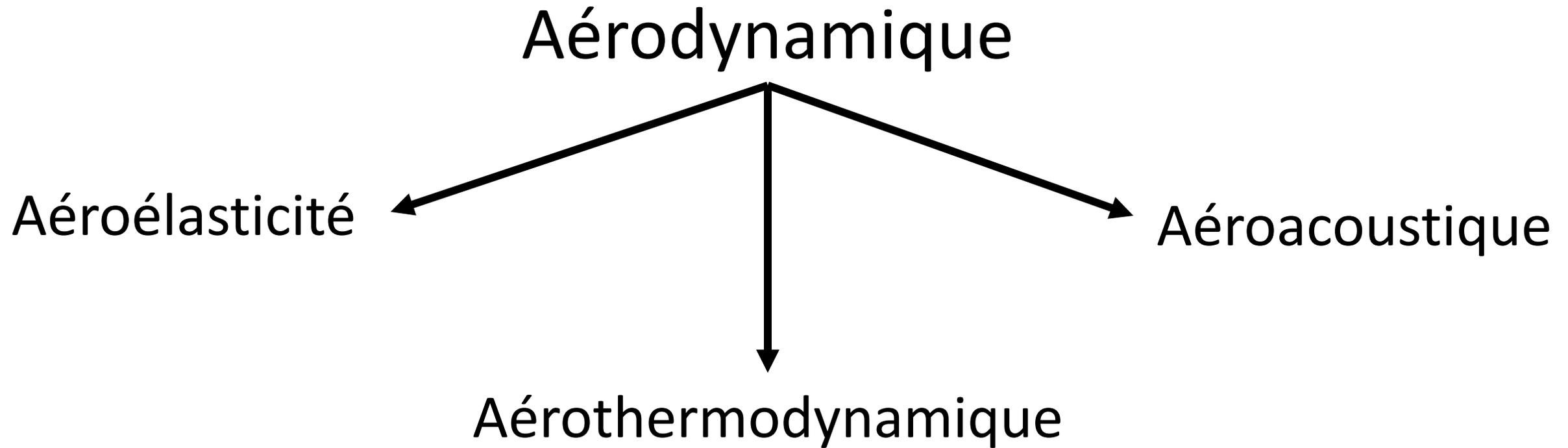
Présentation générale - Les bases en turbulence - Les essais - La CFD - Les simulateurs

Grandes échelles

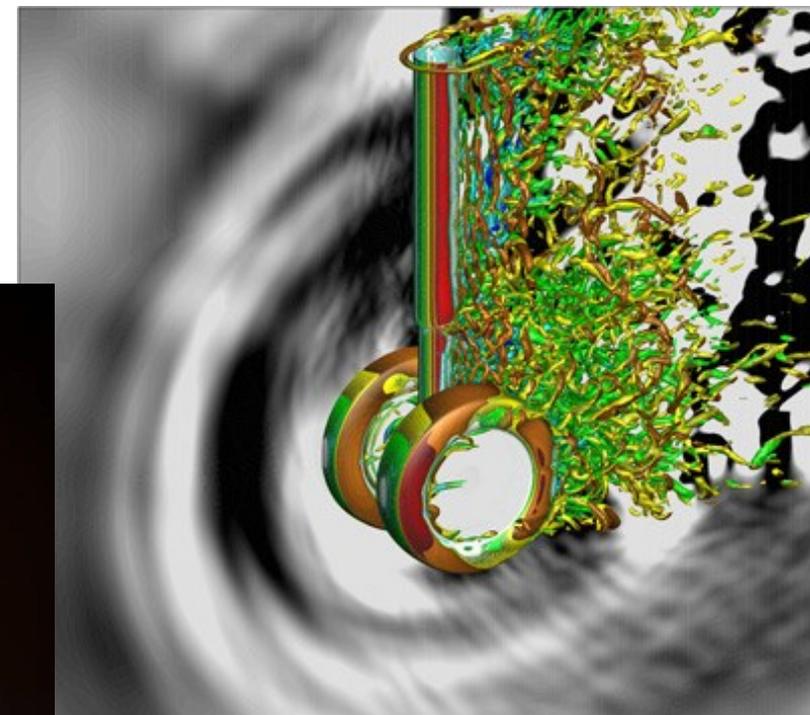


Petites échelles





Aérodynamique



Fluides :

- Liquides
- Gaz
- Plasma



Propriétés d'un écoulement de fluide:

- Viscosité
- Masse volumique
- Température
- Pression
- Vitesse
- ...

Continuity equation :

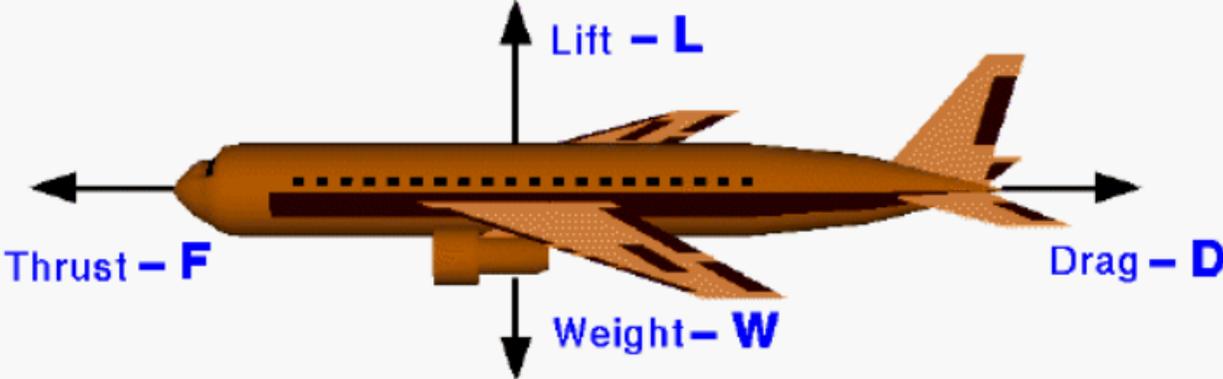
$$\frac{\partial \rho}{\partial t} + [\rho u_j]_{,j} = 0 \quad (1)$$

2nd law of Newton :

$$\frac{\partial \rho u_i}{\partial t} + [\rho u_i u_j + P \delta_{ij}]_{,j} = \rho f_i + \tau_{ij,j} \quad \text{With : } \tau_{ij,j} = \mu [u_{i,jj} + \frac{1}{3} u_{j,ji}] \quad (2)$$

$$\tau_{ij} = \mu [u_{i,j} + u_{j,i} + \frac{2}{3} (u_{k,k} \delta_{ij})]$$

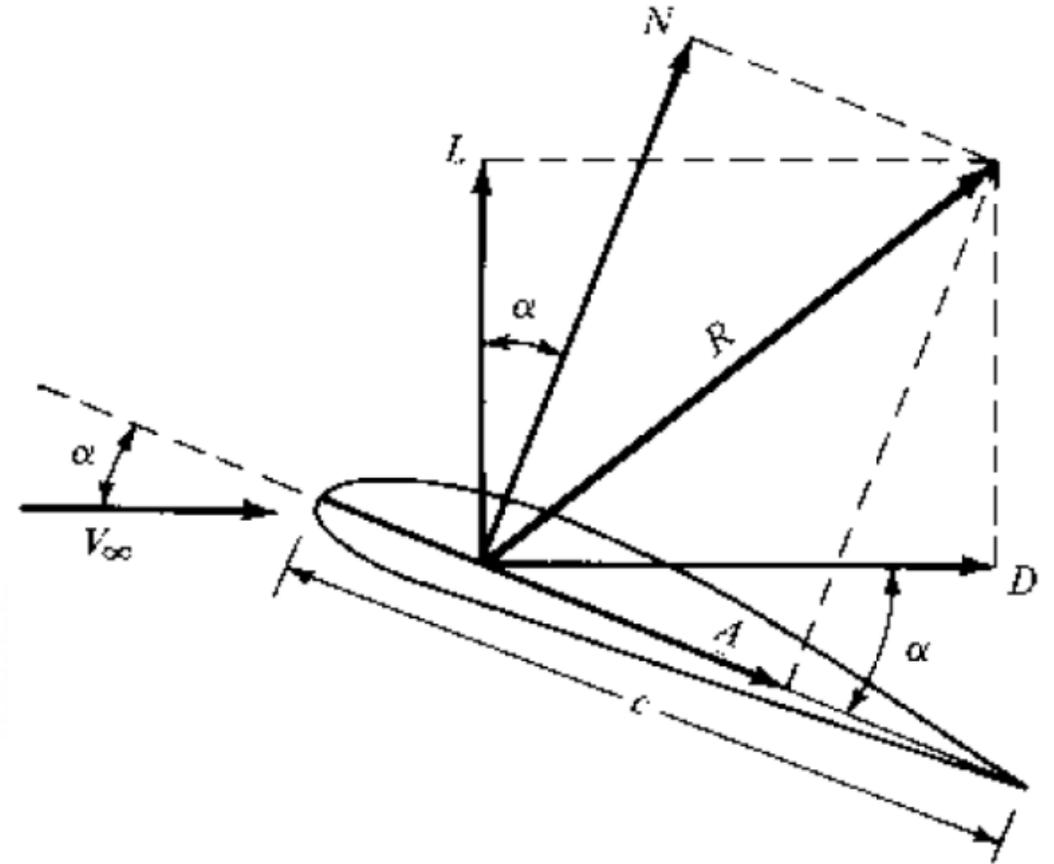
 **Lift to Drag Ratio**
(L/D ratio) Glenn
Research
Center

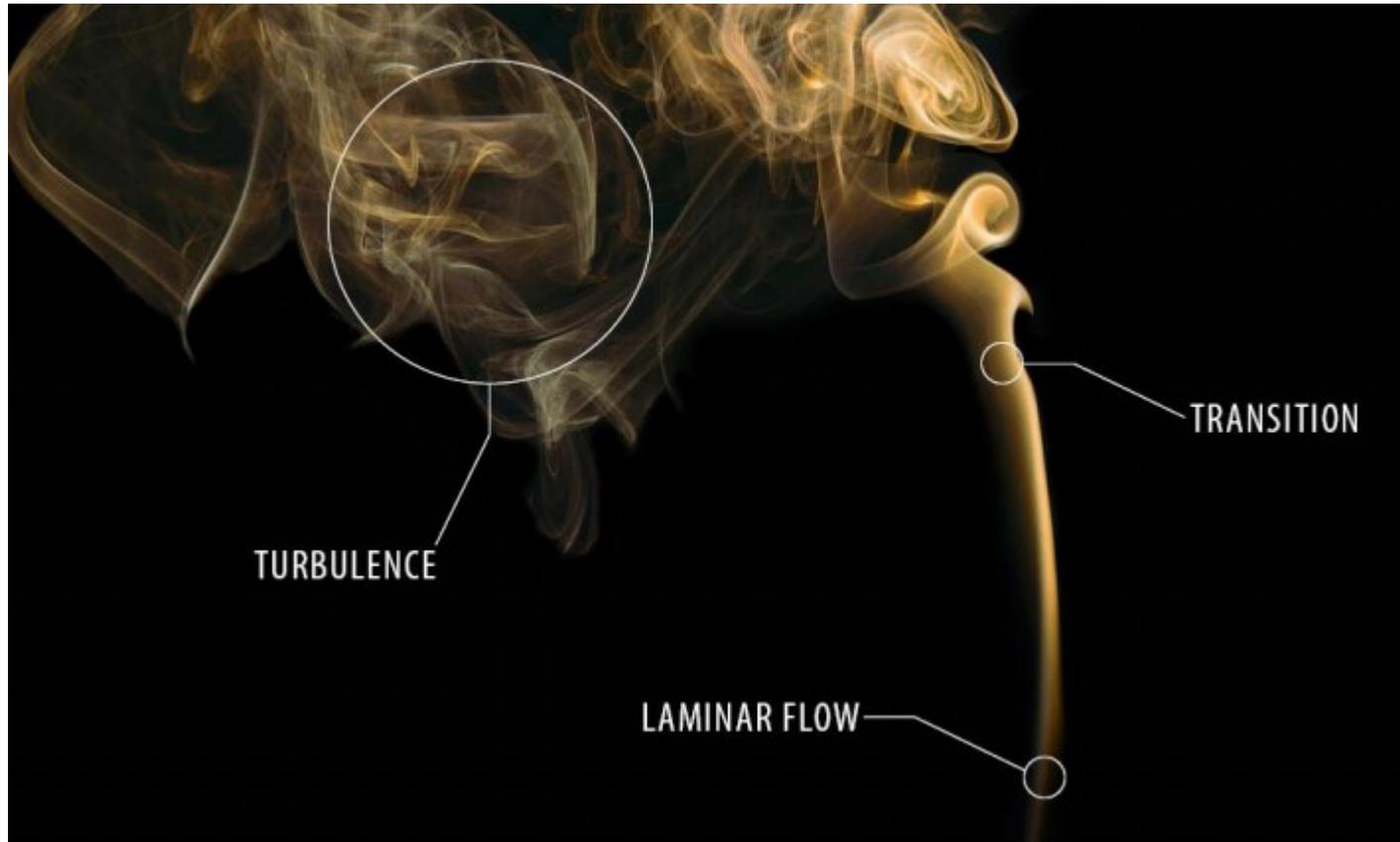


Thrust - F **Lift - L**
Weight - W **Drag - D**

$$\frac{L}{D} = \frac{\text{Lift}}{\text{Drag}} = \frac{C_l (.5 \rho V^2 A)}{C_d (.5 \rho V^2 A)}$$

High L/D = High efficiency = Long range
High L/D = Large payload = Low fuel usage





$$Re = \frac{\text{Forces d'inertie}}{\text{Forces visqueuses}}$$

Le nombre de Reynolds et la turbulence

Présentation générale - Les bases en turbulence - Les essais - La CFD - Les simulateurs



$Re = 100\ 000\ 000$

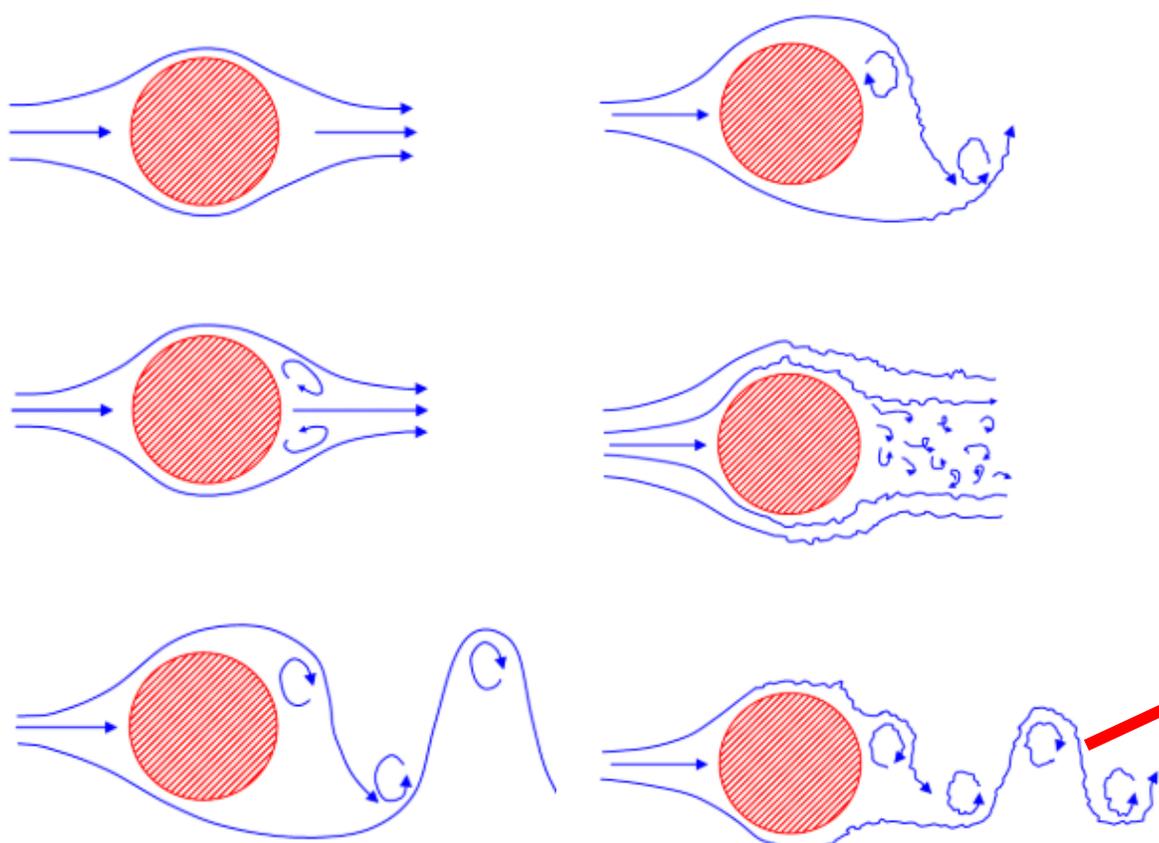


$Re = 1\ 000\ 000$

$Re = 0,2$



Le nombre de Reynolds et la turbulence



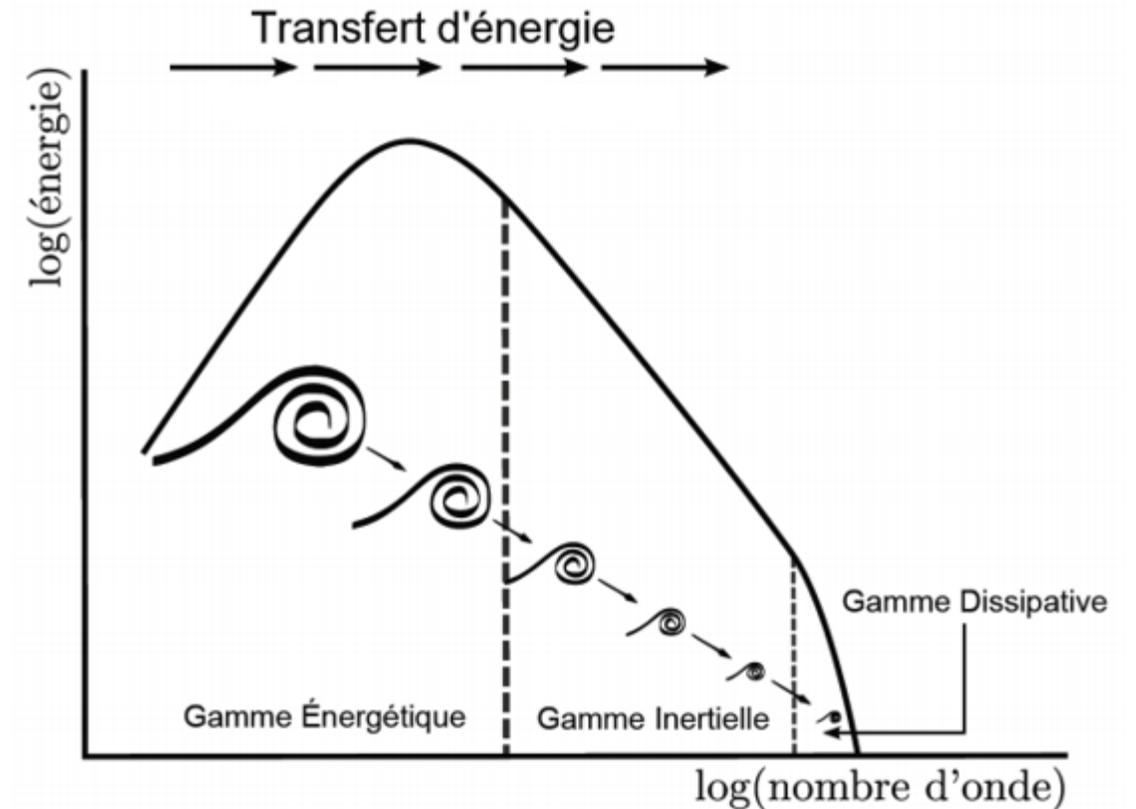
Mais qu'est ce que la turbulence ?

La nature déteste le désordre !

Deux moyens de retourner dans un état ordonné :

- Par frottements visqueux (Faibles vitesses)
- Avec l'aide de la turbulence

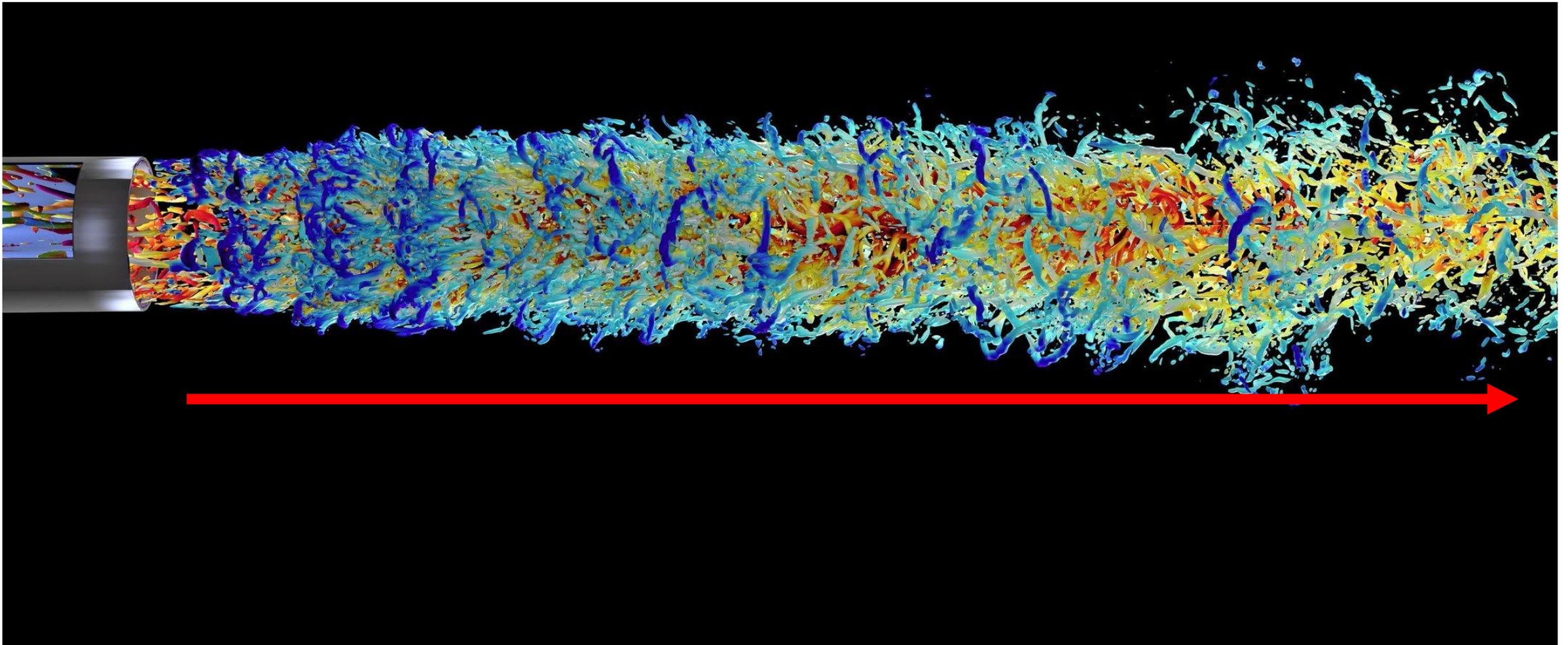
Cisaillement = Turbulence



Spectre typique de turbulence
[Adapté de Lemay, J., Université Laval (2010)]

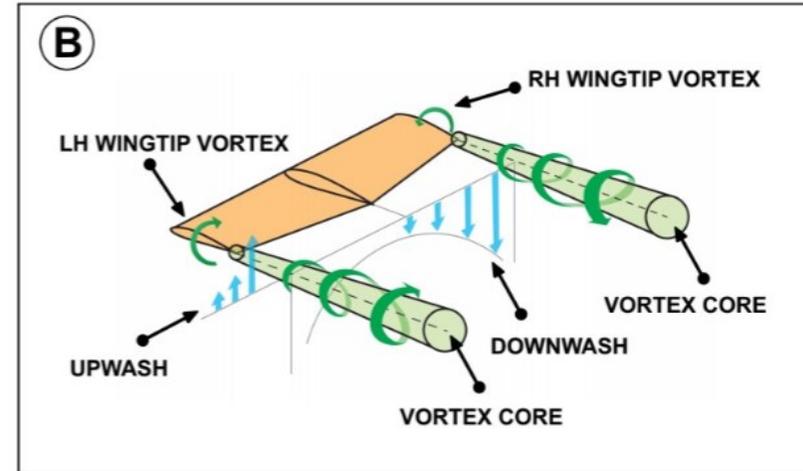
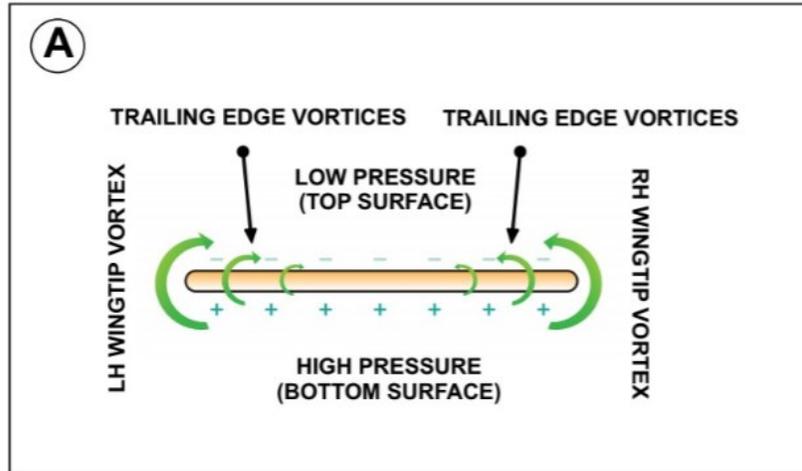
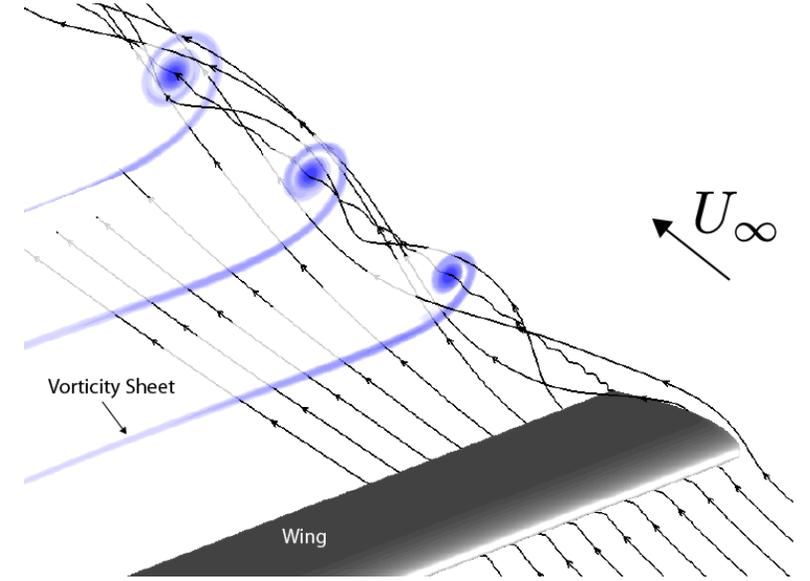
Mais qu'est ce que la turbulence ?

Présentation générale - **Les bases en turbulence** - Les essais - La CFD - Les simulateurs





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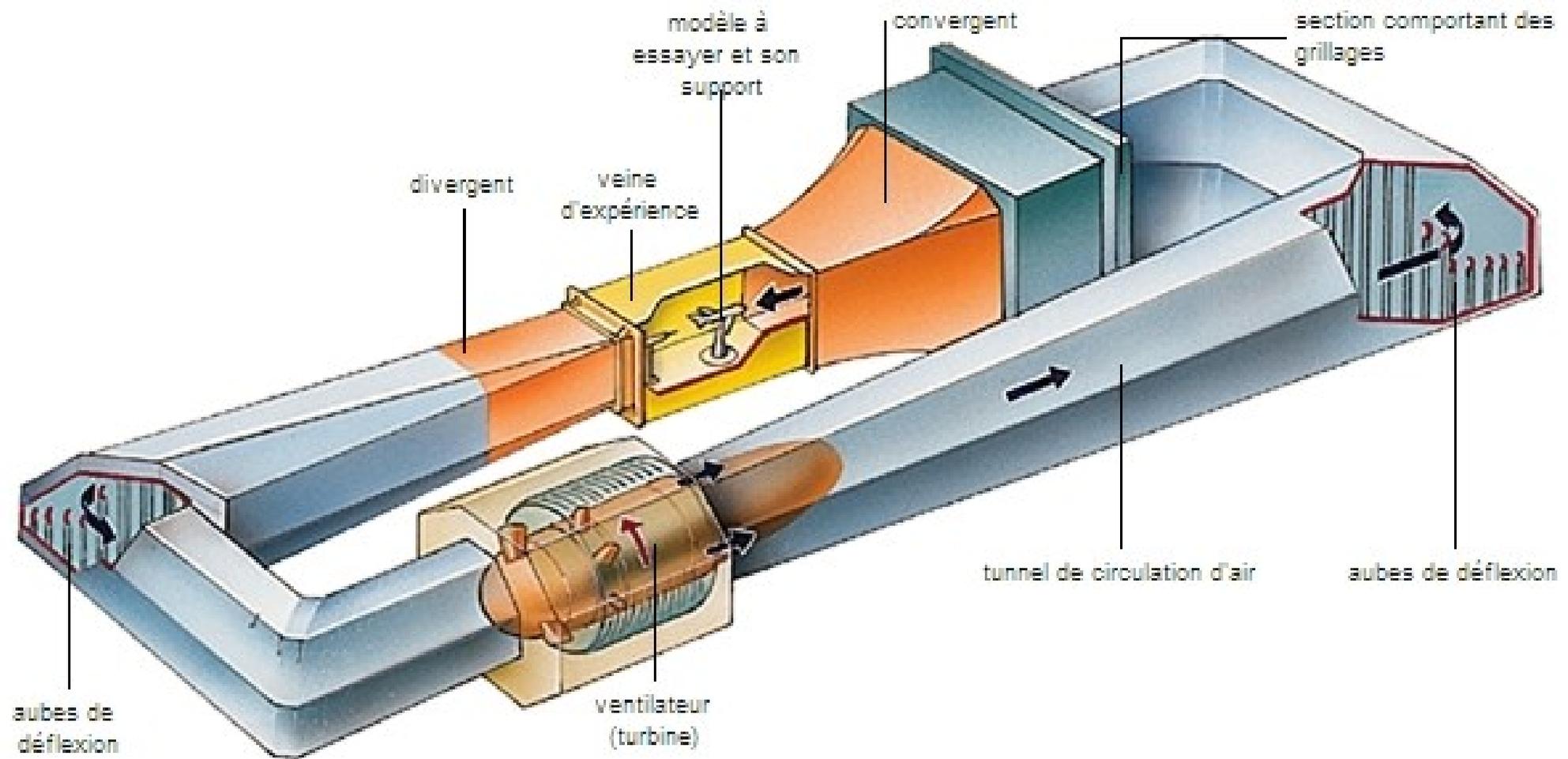
Questions

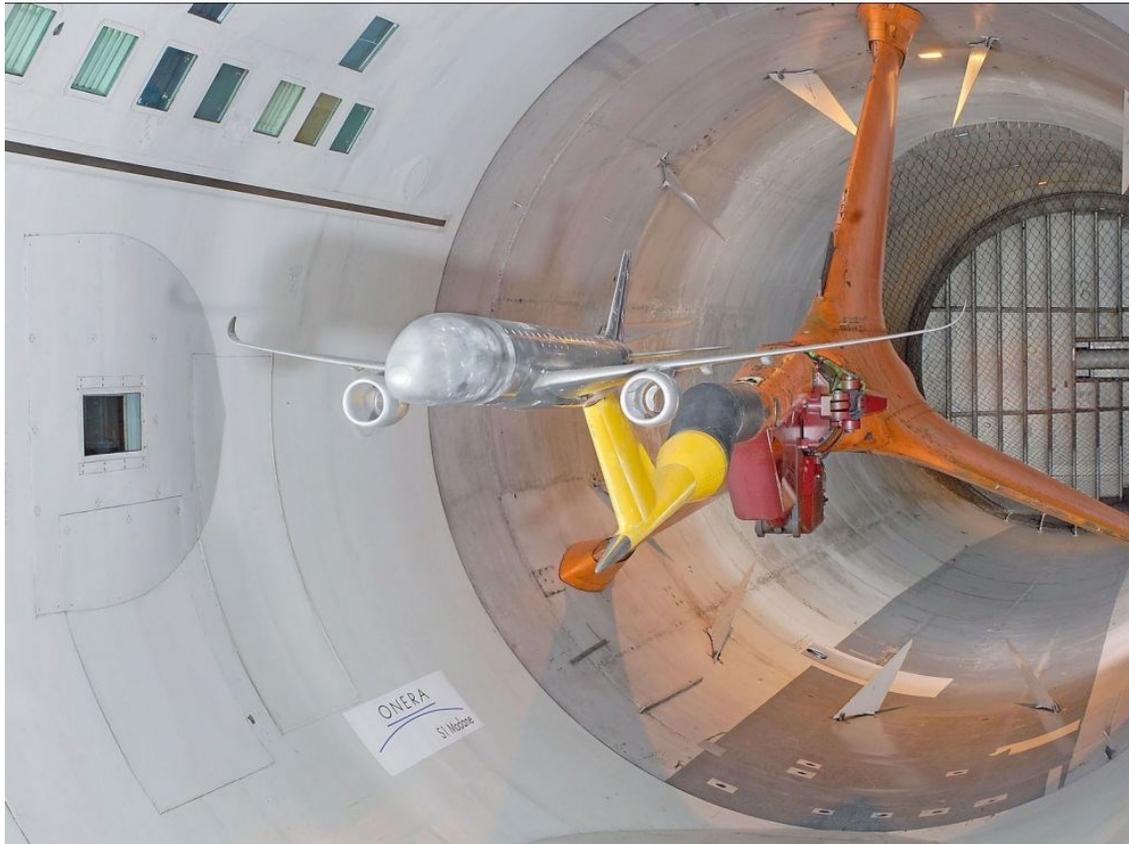


Petite pause

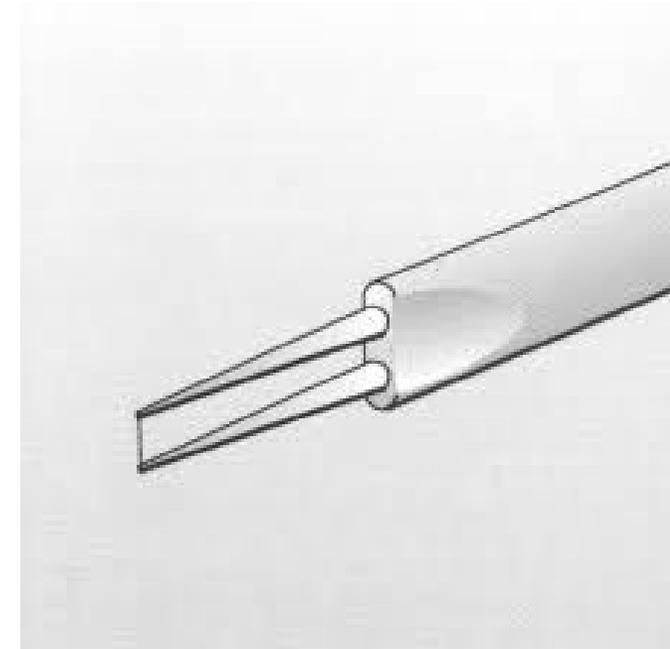
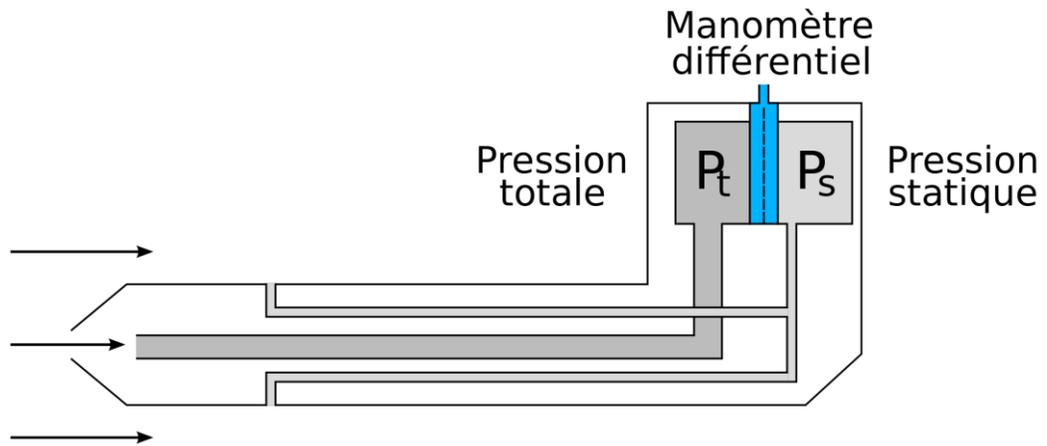
N'hésitez pas à poser vos questions dans le chat

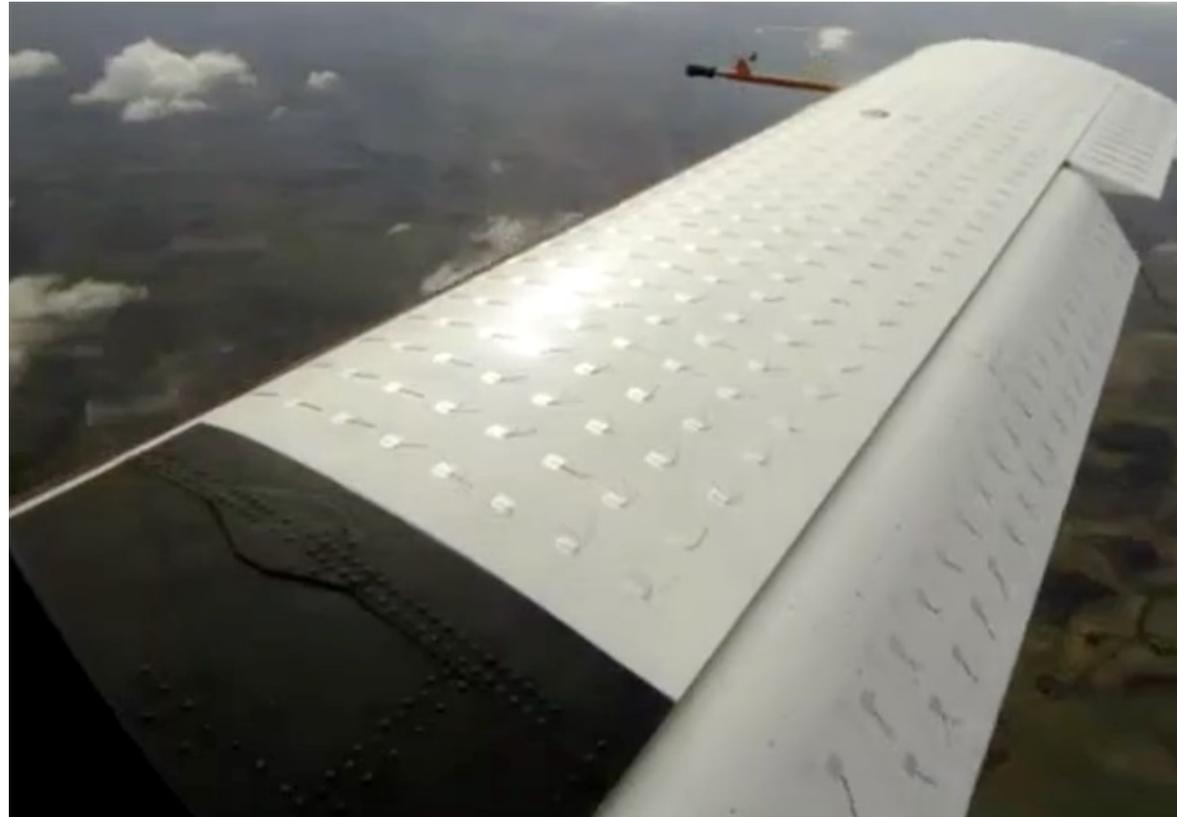


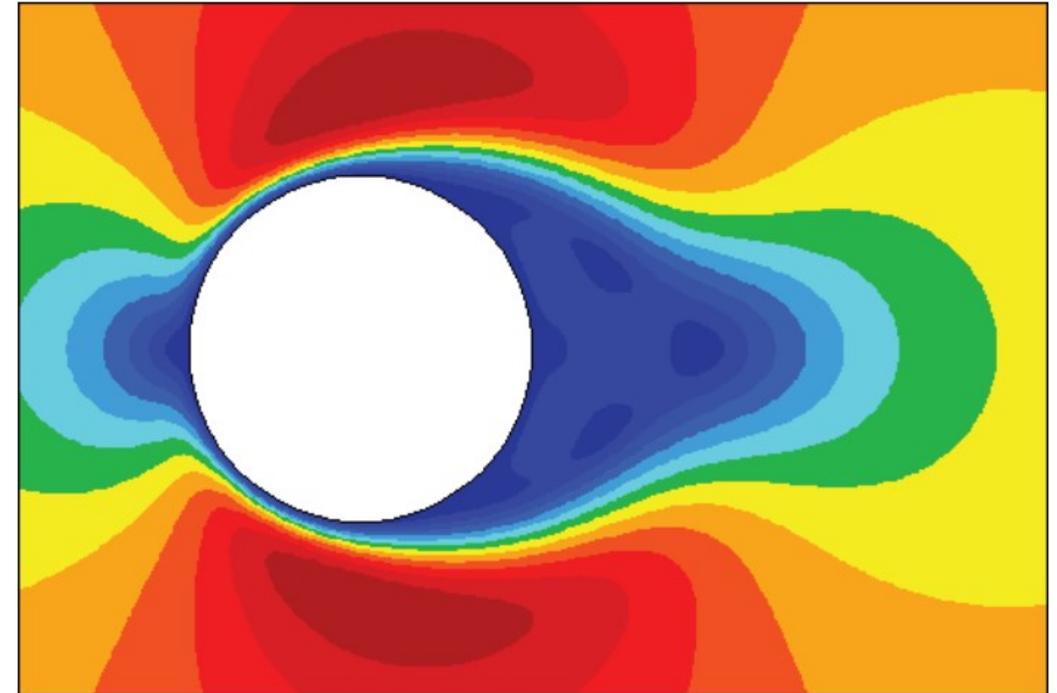
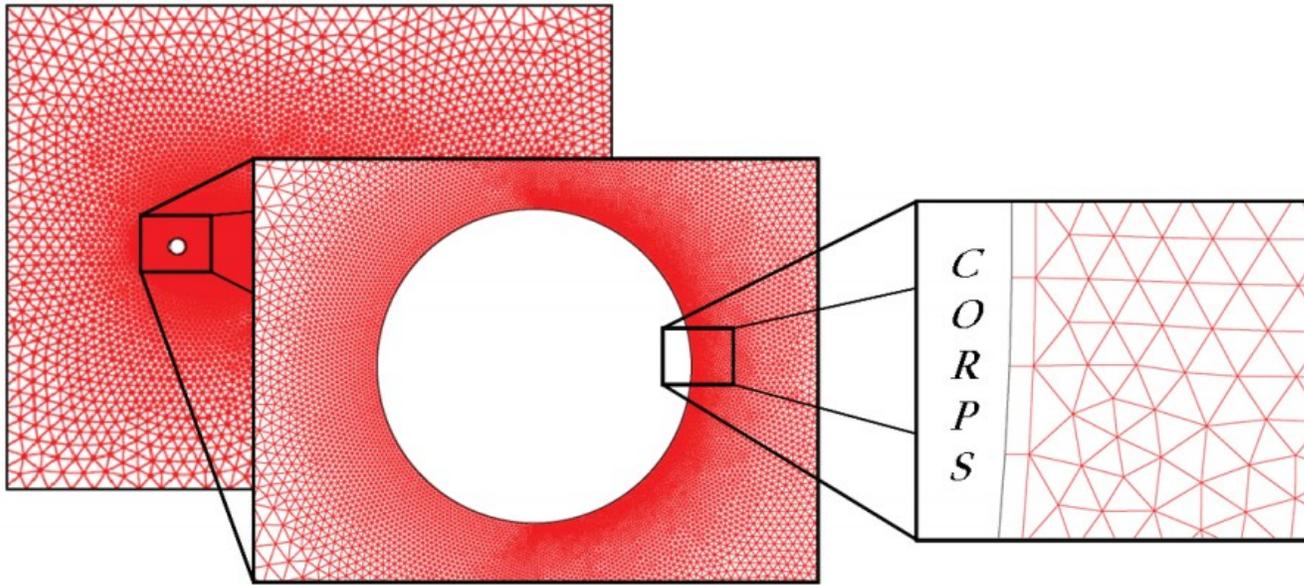




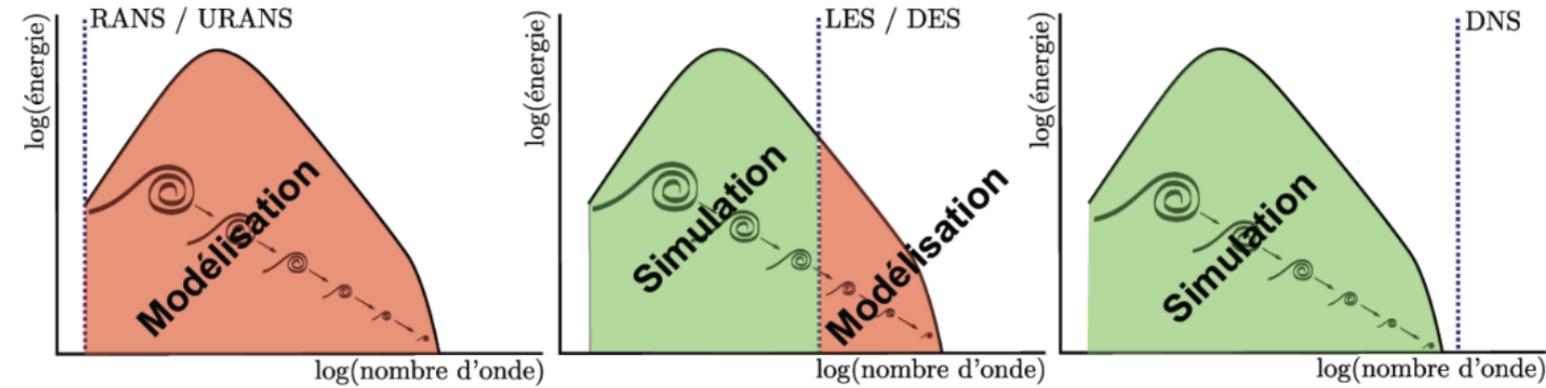
Soufflerie de l'ONERA sur le site de Modane (Savoie)



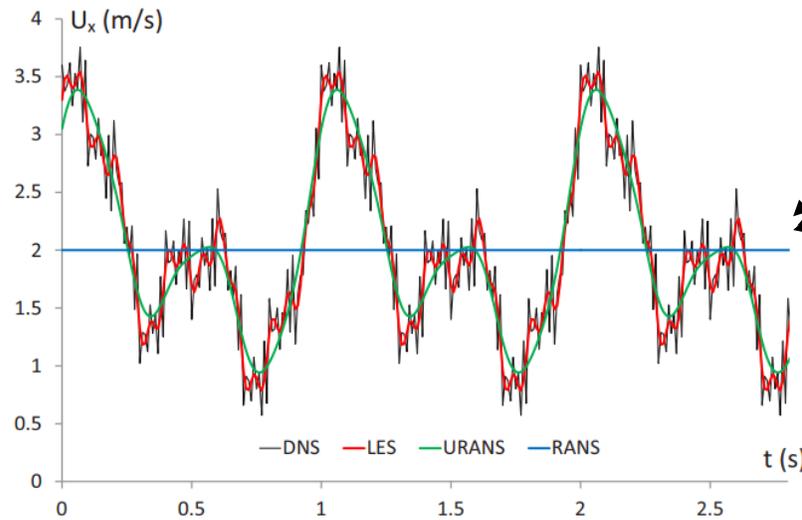
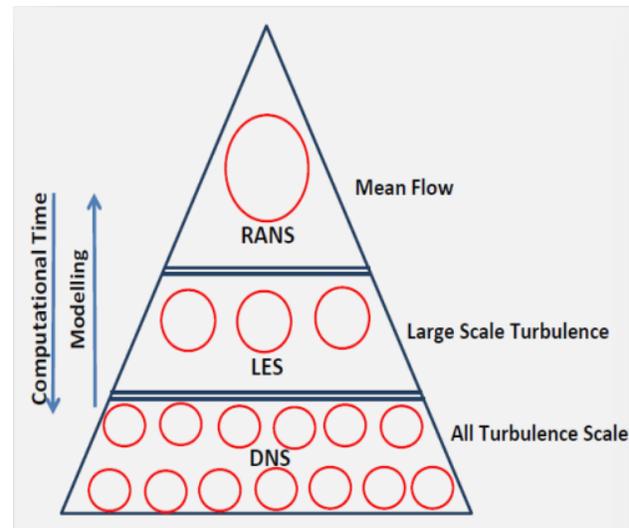
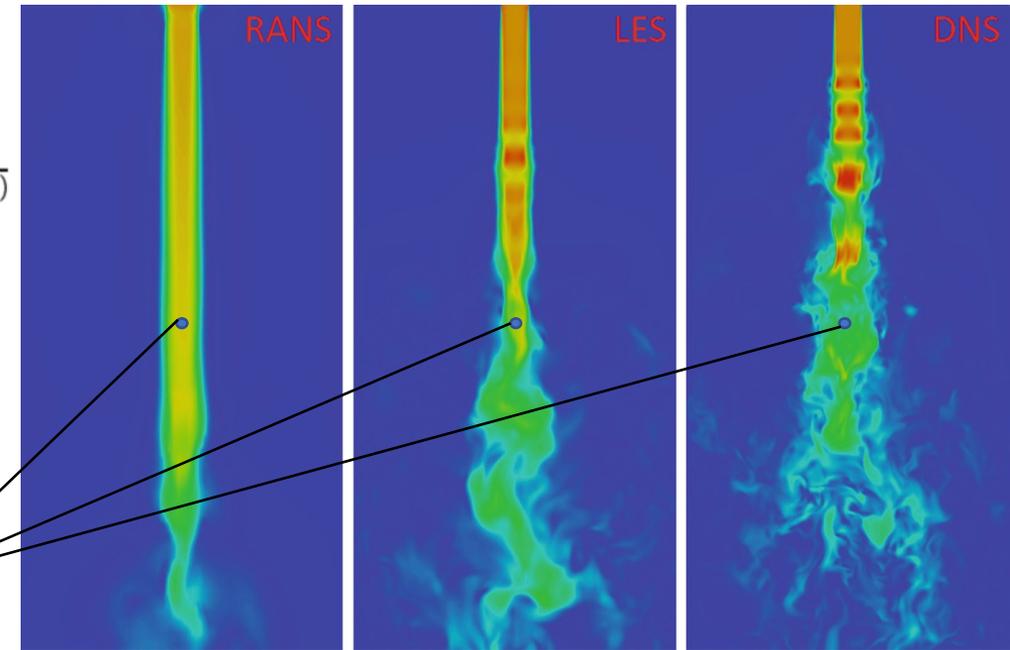




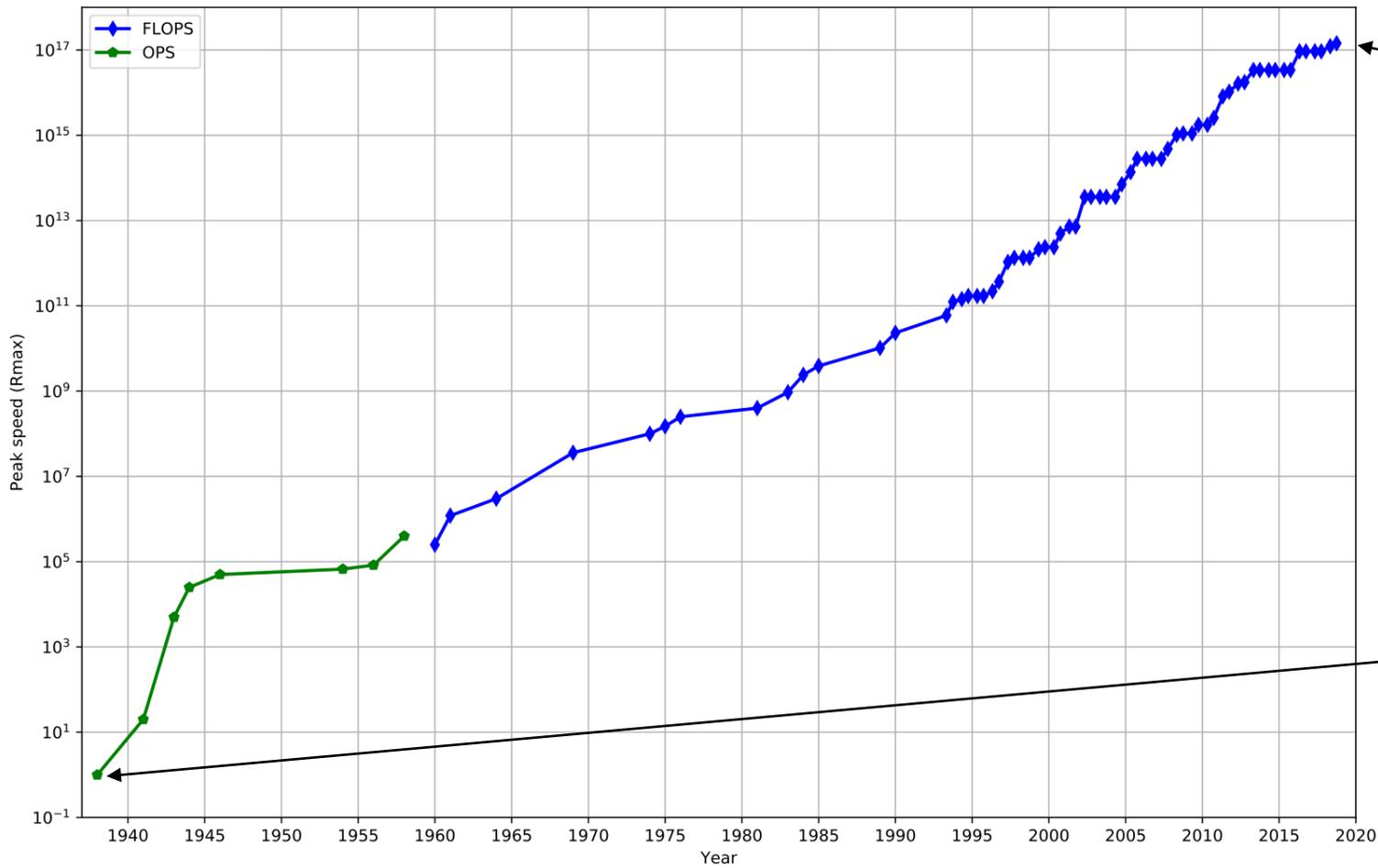
Maillage et contour de pression autour d'un Cylindre
[Image de Bochud, P. et Lefrançois, J., Université Laval (2006)]



Simulation et modélisation du spectre de turbulence
 [Image de Beaubien, C.-A., Université Laval (2013)]



L'évolution de la puissance de calcul



Fugaku



Z1



LES :

<https://www.youtube.com/watch?v=ks45Qweltlc>

<https://www.youtube.com/watch?v=uYgkNMlnAsQ>

DNS :

<https://www.youtube.com/watch?v=aR-hehP1pTk>

<https://www.youtube.com/watch?v=9MnUiQVs3kQ>

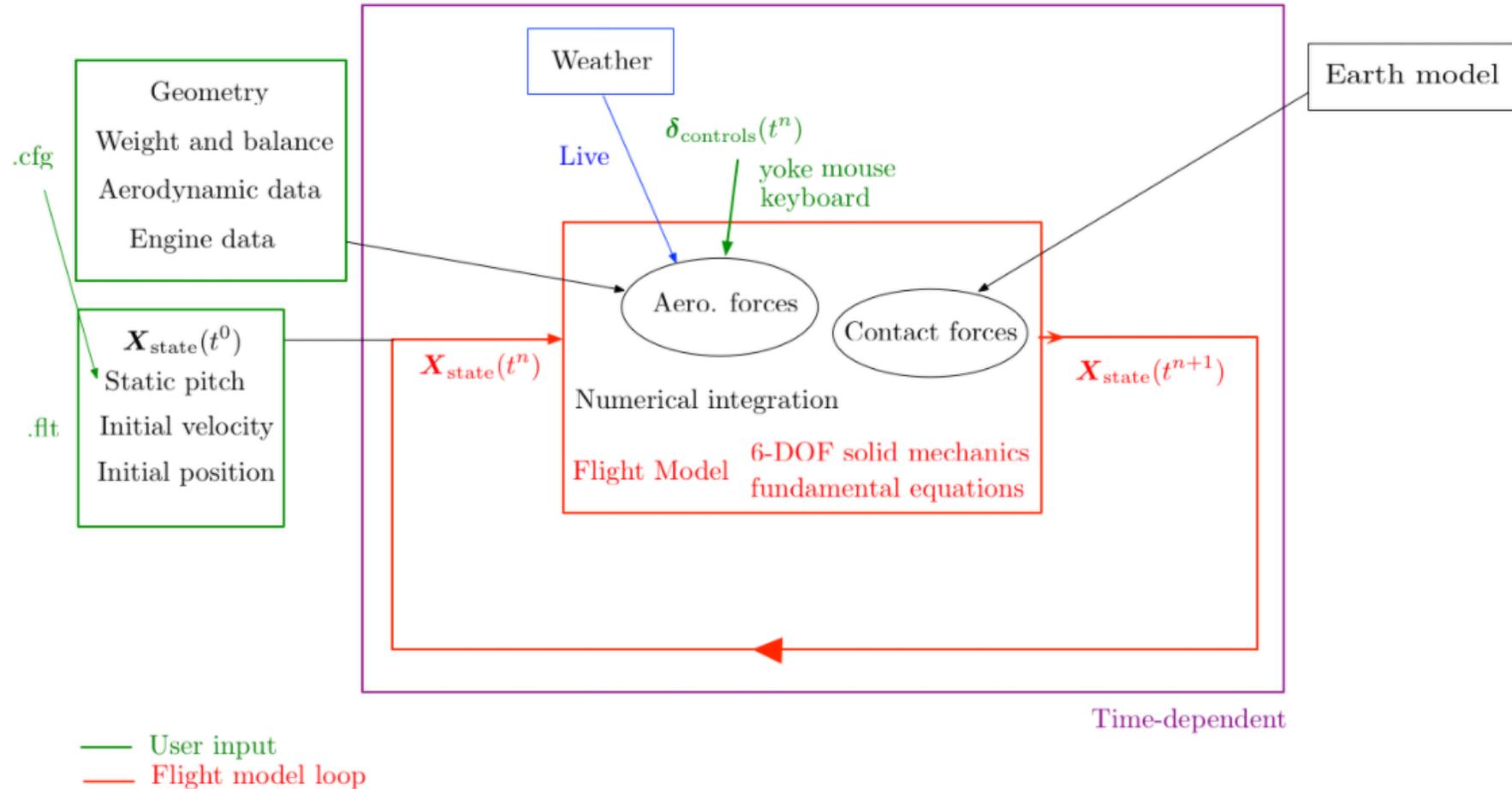


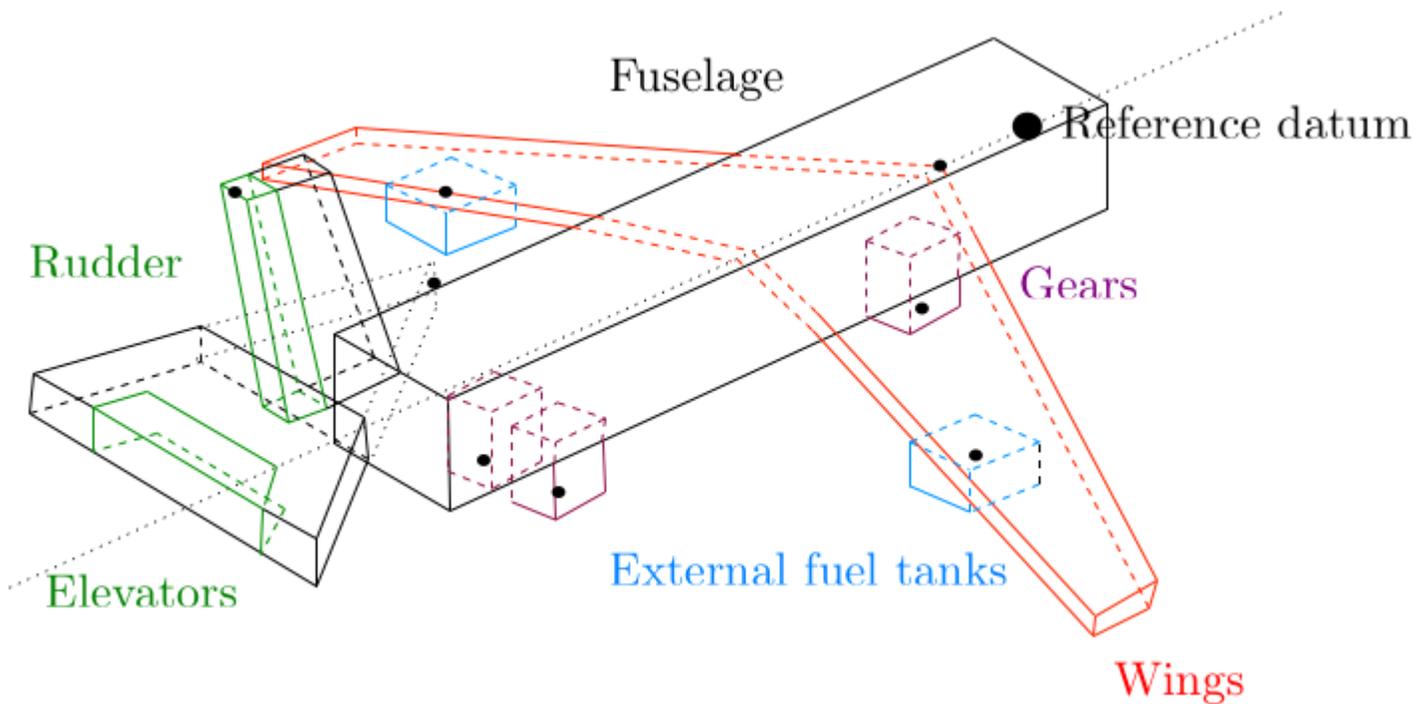
Questions





Qu'est ce qu'un modèle de vol dynamique ?





- 40×3 for the fuselage, assimilated to an elongated rectangular box
- 1×3 for the gears, a box
- 1×3 for each external fuel tank, box
- 20×3 vertical tail and rudder
- 20×3 for horizontal tail and elevators
- 80×5 for each wing



Conclusion

Des questions ?

