Principali attività di ricerca in corso e sviluppi futuri

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SAPIENZA
UNIVERSITÀ DI ROMA

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Research group and themes

Research team members

- Sergio Pirozzoli (PA)
- Matteo Bernardini (RTD)
- Ioannis Asproulias (AR)
- Russell Quadros (AR)
- Davide Modesti (Phd)
- Antonio Memmolo (Phd)
- Luca Saccoccio (Phd)

Research interests

- Foundamental physics of turbulent flows (low- and high-speed)
  - Shock wave/boundary layer interactions
  - DNS/LES of high-Reynolds number wall-bounded flows
  - DES of turbulent flows in complex configurations
  - Superhydrophobic and liquid infused surfaces
  - Particle dispersion in turbulent flows
  - Control of wall-bounded flows
  - Heat transfer, free and mixed convection
- Development of high-order accurate and efficient numerical methods

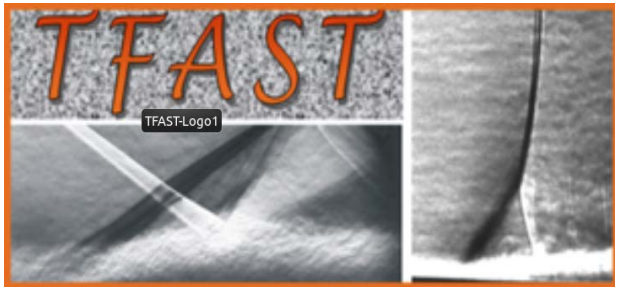
Main research grants

- **FP6 Project (UFAST)** – Unsteay effects in shock wave induced separation (2006-2010, 220k €)
  Personnel: Pirozzoli (PI), Bernardini, Beer, Grasso

- **FP7 Project (TFAST)** – Transition location effect on shock wave boundary layer interaction (2012-2016, 300k €)
  Personnel: Pirozzoli (PI), Bernardini

- **PRIN 2012** – Analysis and control of transitional flows on lifting surfaces (2014-2017, 112k €)
  Personnel: Pirozzoli (PI), Bernardini, Memmolo, Modesti

- **SIR 2014 (jACOBI)** – Active control of shock wave boundary layer interaction (2015-2019, 603k €)
  Personnel: Bernardini (PI), Pirozzoli, Asproulias, Quadros



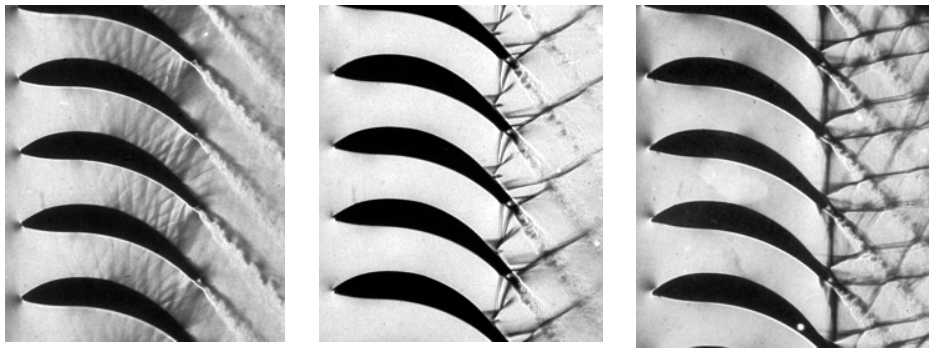
Shock boundary layer interactions (SBLI)

Flows of technological interest

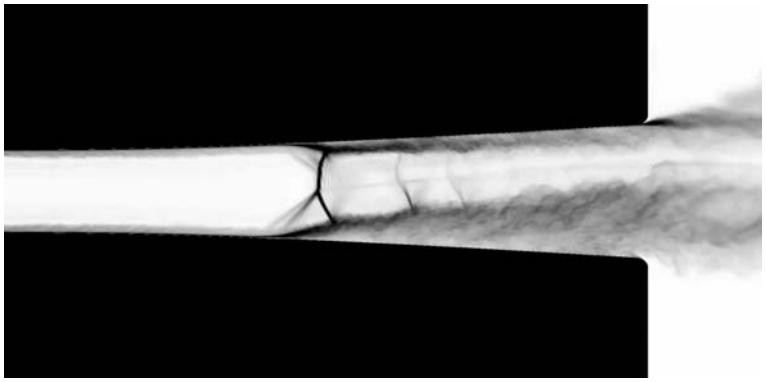
- Space launchers in ascent phase (Vega)
- Over-expanded nozzles
- Transonic wings
- Engine intakes

Detrimental SBLI features

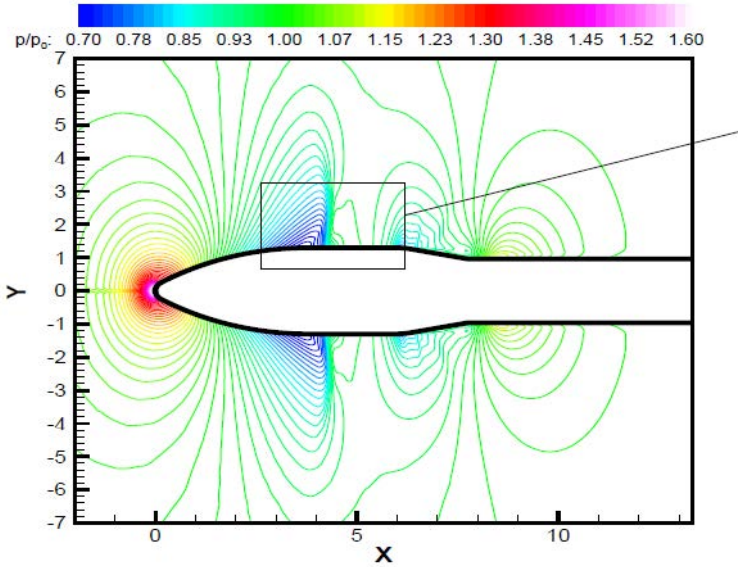
- Mechanical and thermal loads
- Loss of efficiency
- Turbulence amplification and noise



Turbine blades



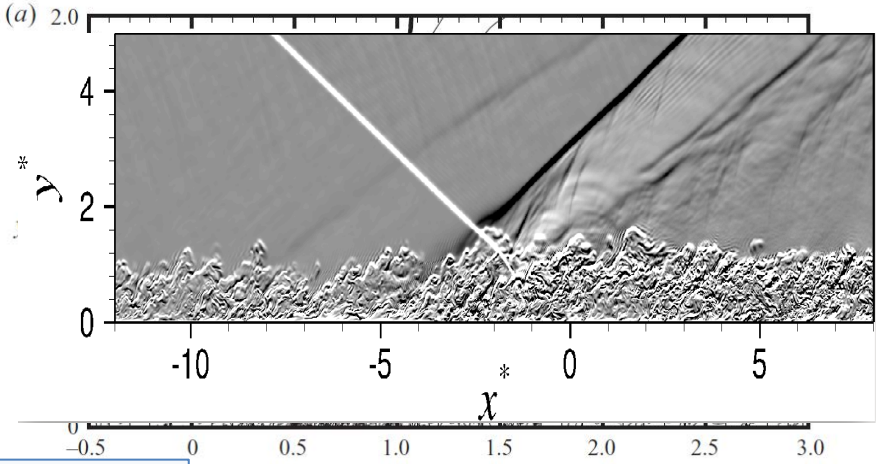
Over-expanded nozzle



Flow solver development

Numerical issues

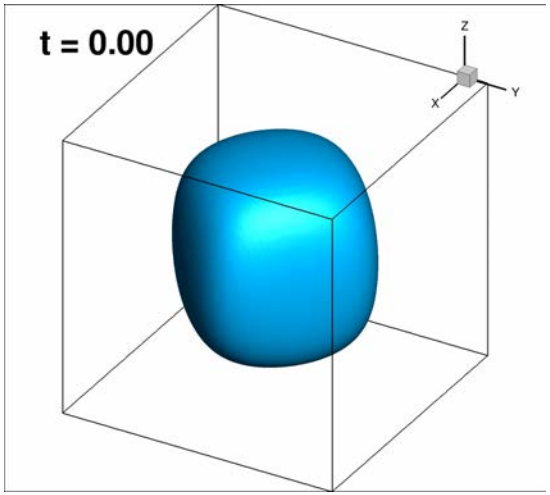
- Simulation of flow fields involving shock waves and turbulence is a challenging task
- Need to compute disturbances of small amplitude and to handle flow discontinuities
- Good resolution properties and robustness
- Computational efficiency, excellent scalability



Energy consistent schemes (FD)

- Discrete conservation of the total kinetic energy
- No spurious numerical dissipation needed (filtering, upwinding)
- Convective terms of NS cast in split form

$$\frac{\partial \rho u_j \varphi}{\partial x_j} = \frac{1}{4}\frac{\partial \rho u_j \varphi}{\partial x_j} + \frac{1}{4}\left(u_j \frac{\partial \rho\varphi}{\partial x_j} + \rho \frac{\partial u_j \varphi}{\partial x_j} + \varphi \frac{\partial \rho u_j}{\partial x_j}\right) + \frac{1}{4}\left(\rho u_j \frac{\partial \varphi}{\partial x_j} + \rho\varphi \frac{\partial u_j}{\partial x_j} + u_j \varphi \frac{\partial \rho}{\partial x_j}\right),$$

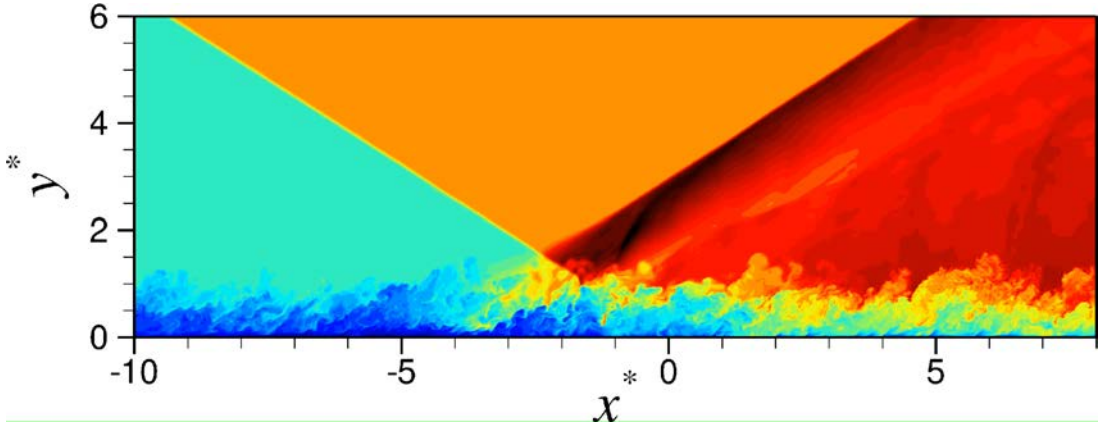


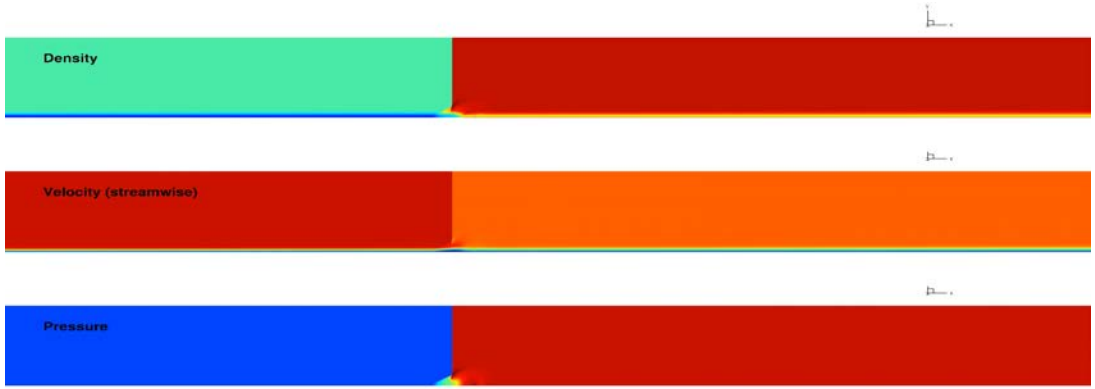
✓ ***S. Pirozzoli, Annu. Rev. Fluid Mech., Vol 43 (2011)***

Canonical SBLI interactions

Collaboration with Stanford University (S.K. Lele, J. Larsson)

❑ DNS of laminar, transitional and turbulent interactions



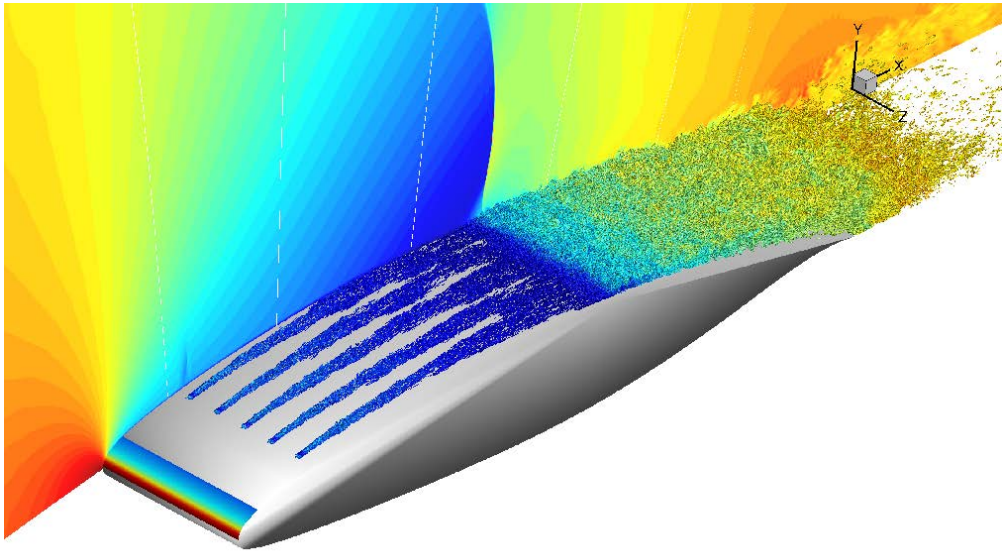


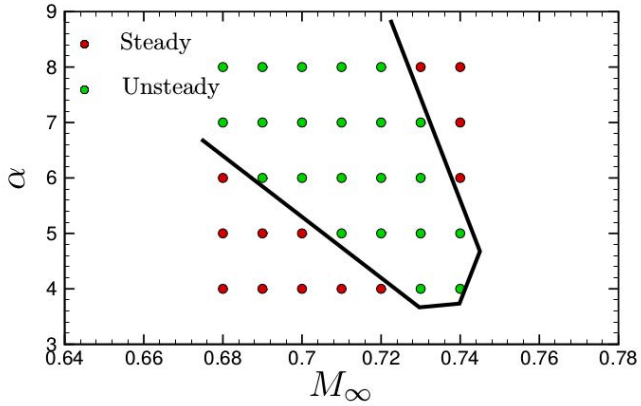
TFAST activities (V2C airfoil)

Collaboration with Dassault Aviation (F. Billiard)

Buffet limit for transonic airfoil

- Laminar airfoil designed by Dassault (V2C)
- Explore buffet limit in the M-AoA plane
- Effect of BL tripping



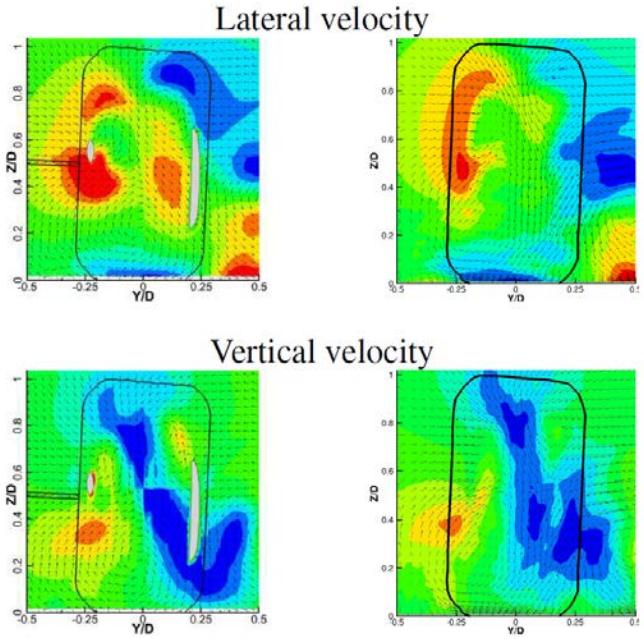


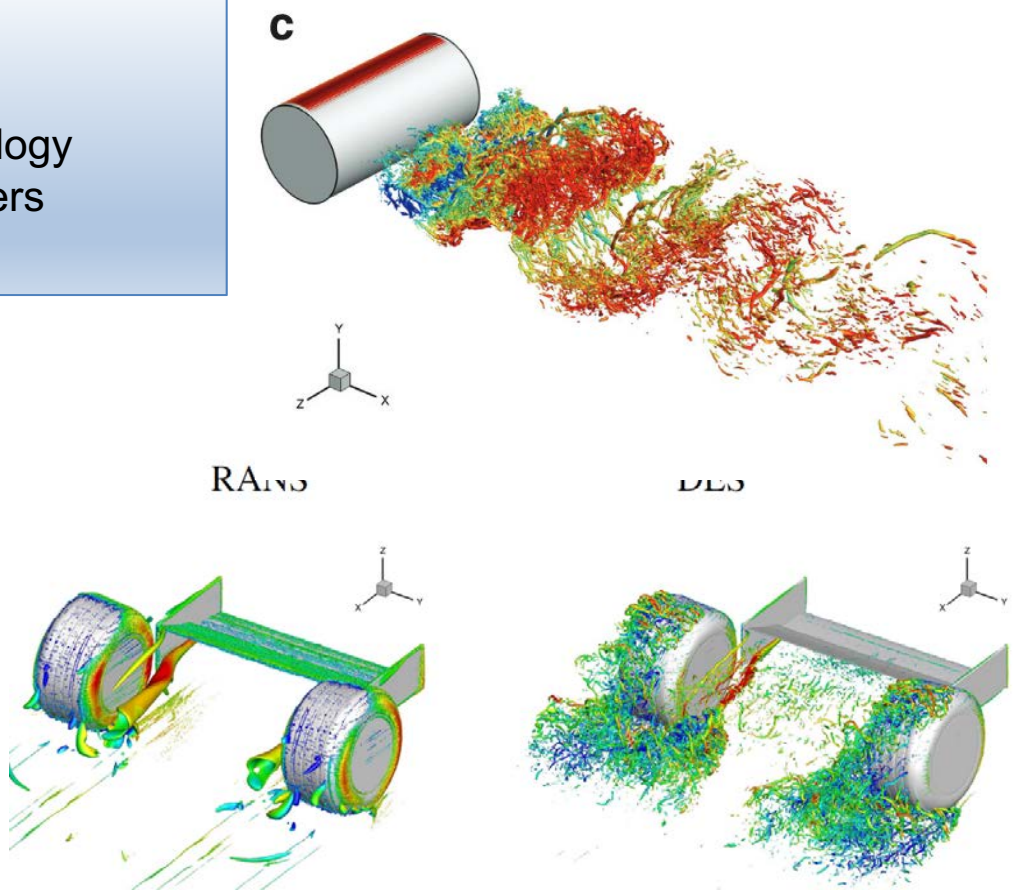
DES of turbulent flows in complex configurations

Collaboration with Toro Rosso (F. Tessicini)

Flow solver development

- Coupling IB method with DES methodology
- Use of wall functions for high Re numbers
- Manage complex geometries (STL)

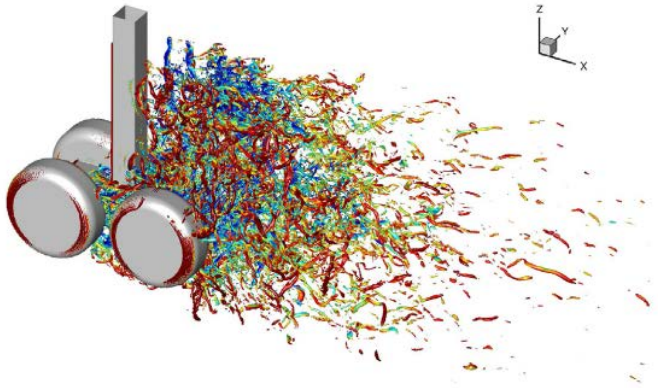


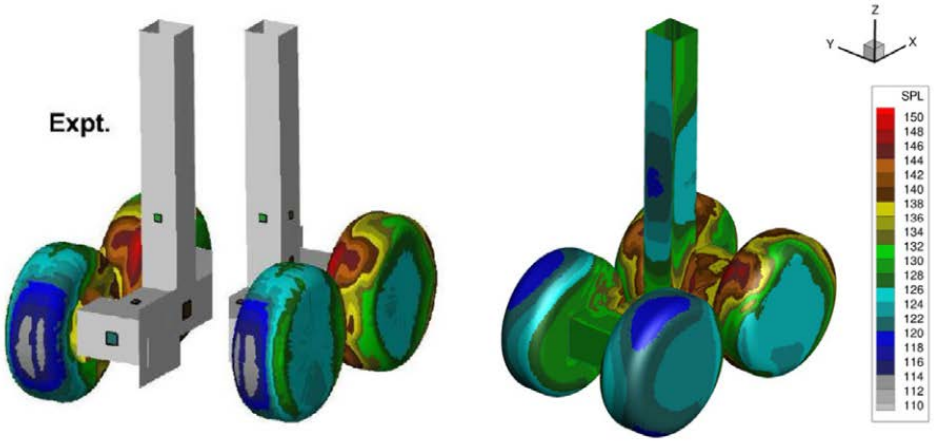


PIV (left) vs DES (right)

Main outcomes

- Accurate prediction of flows with massive separation
- Need for LGR strategy





b

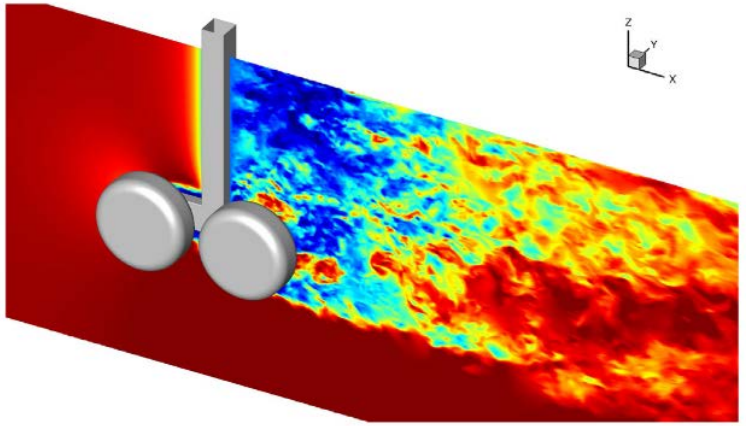


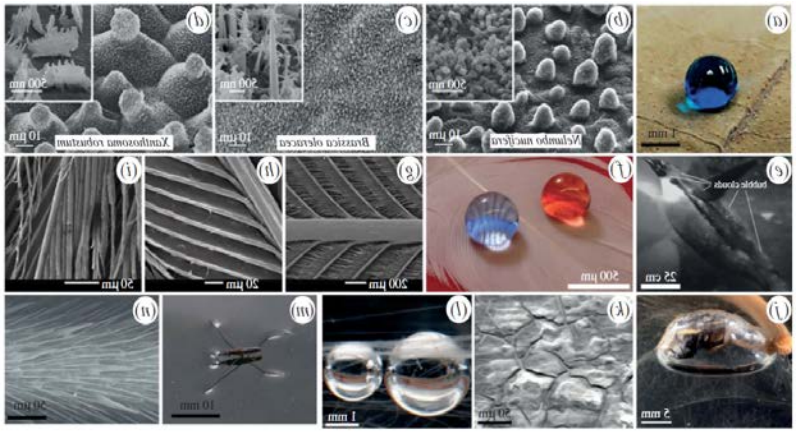
Fig. 9. Visualization of flow around RLG. Vortical structures detected using the swirling strength criterion (a) and contours of streamwise velocity in the x–y plane at $z = 0$ (b).

Superhydrophobic and Liquid infused surfaces

Collaboration with UT Dallas (S. Leonardi)

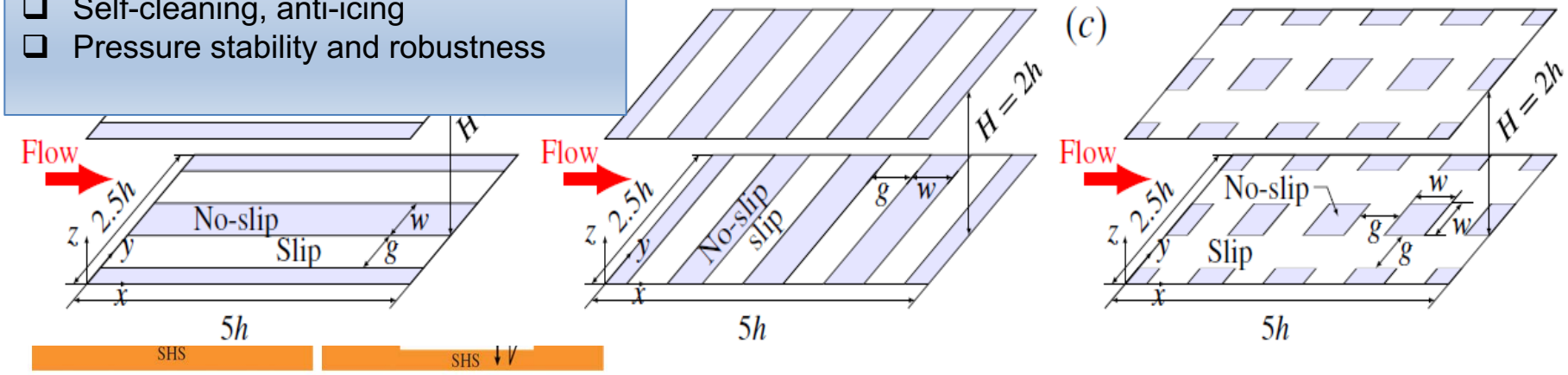
SHS (super hydrophobic)

- Large contact angle and low contact-angle hysterisis
- Surface roughness and chemical inhomogeneity
- Micro- or nanometer-sized surface features
- Friction drag reduction achieved by sustaining a shear-free air-water interface
- Lack of robustness



LIS (Liquid infused)

- Liquid lubricant
- Self-cleaning, anti-icing
- Pressure stability and robustness

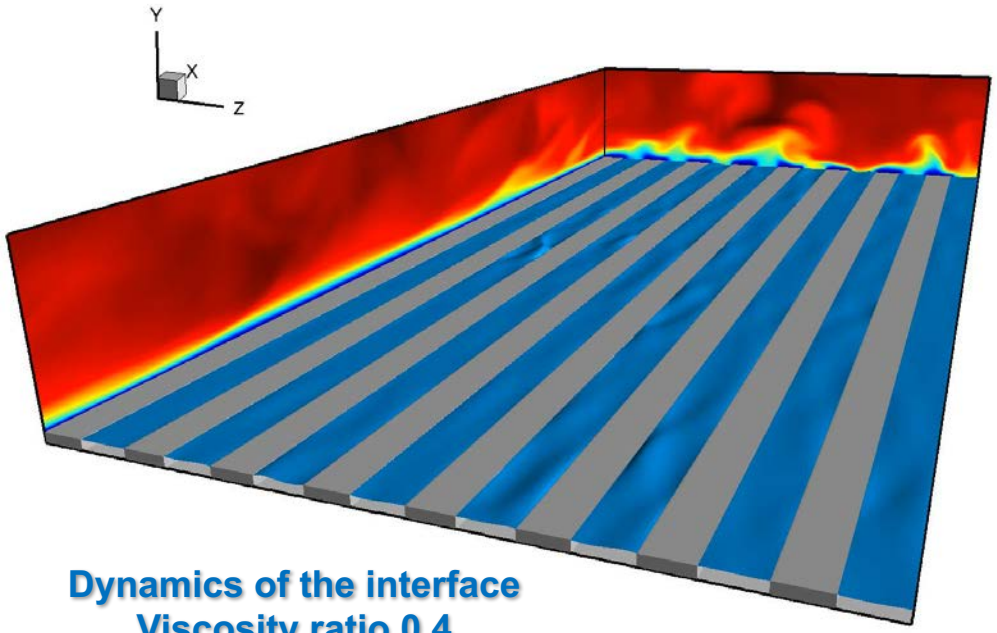


Superhydrophobic and Liquid infused surfaces

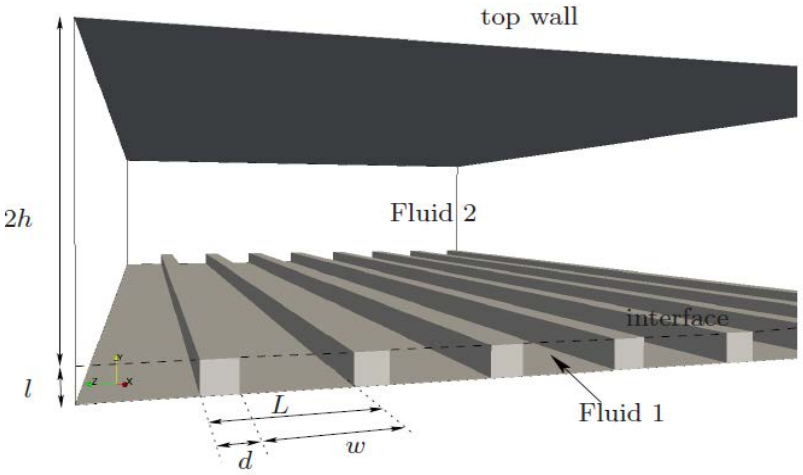
Collaboration with UT Dallas (S. Leonardi)

State-of-the-art flow solver

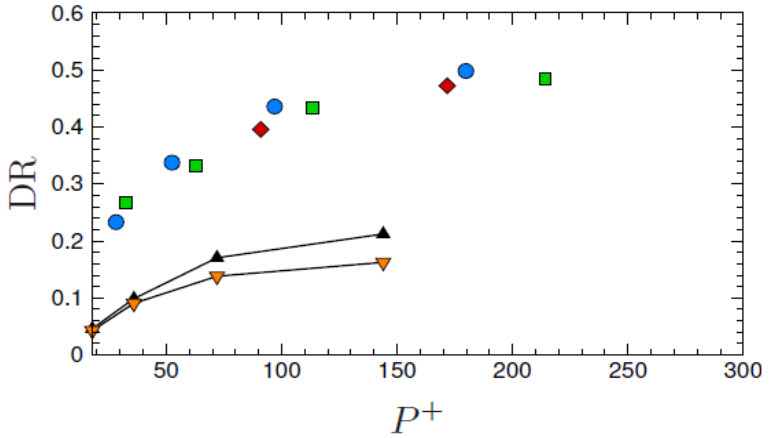
- ❑ DNS of channel flow with immersed boundary method
- ❑ Level set approach to manage two-phase flow
- ❑ Dynamic of the interface in the computation



Dynamics of the interface
Viscosity ratio 0.4



Computational setup



Drag reduction vs pitch