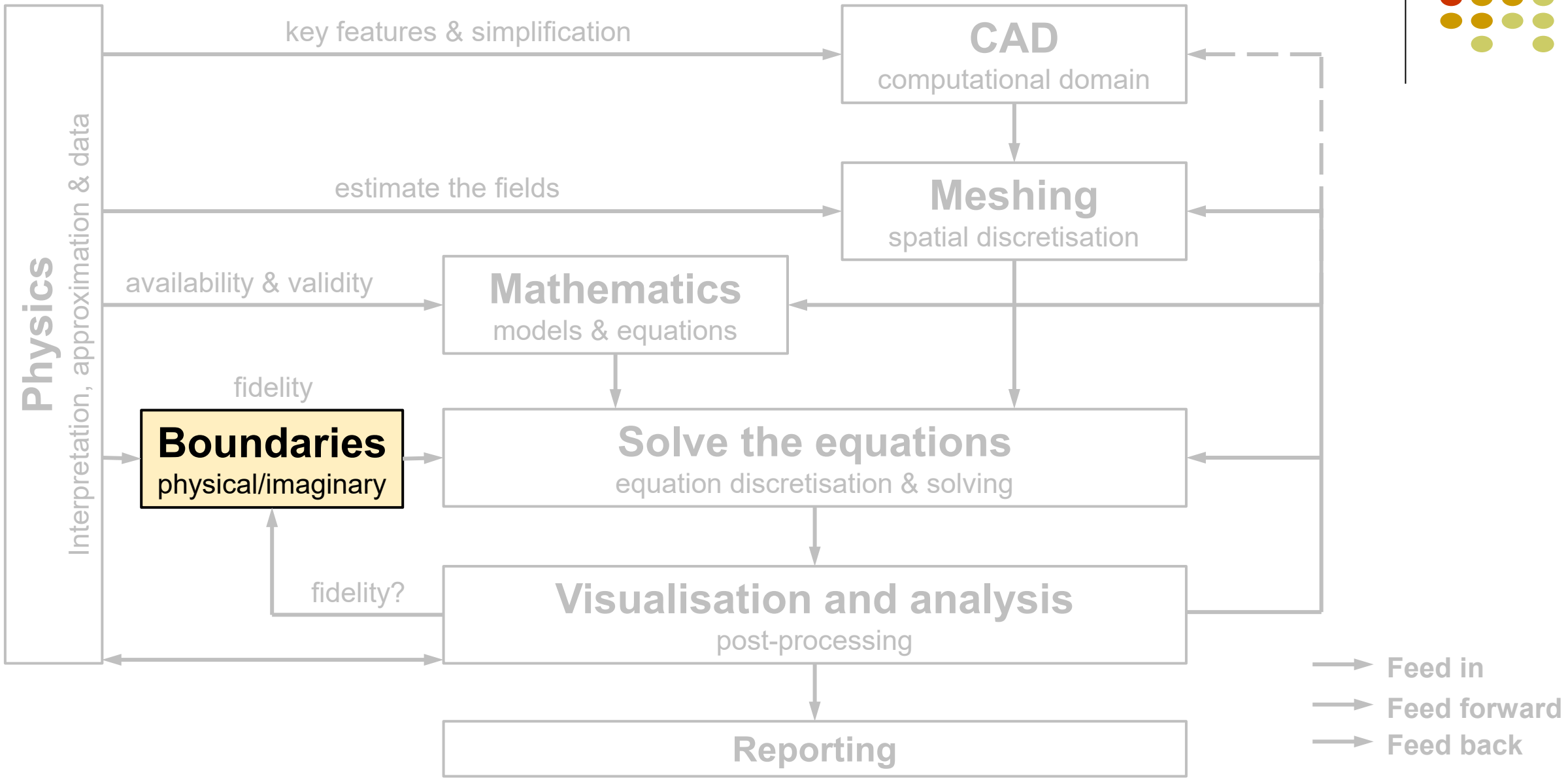
ENIGNEERING COMPUTATIONAL FLUID DYNAMICS (ECFD)

Dr Xiangdong Li

Module 7 – Boundary conditions

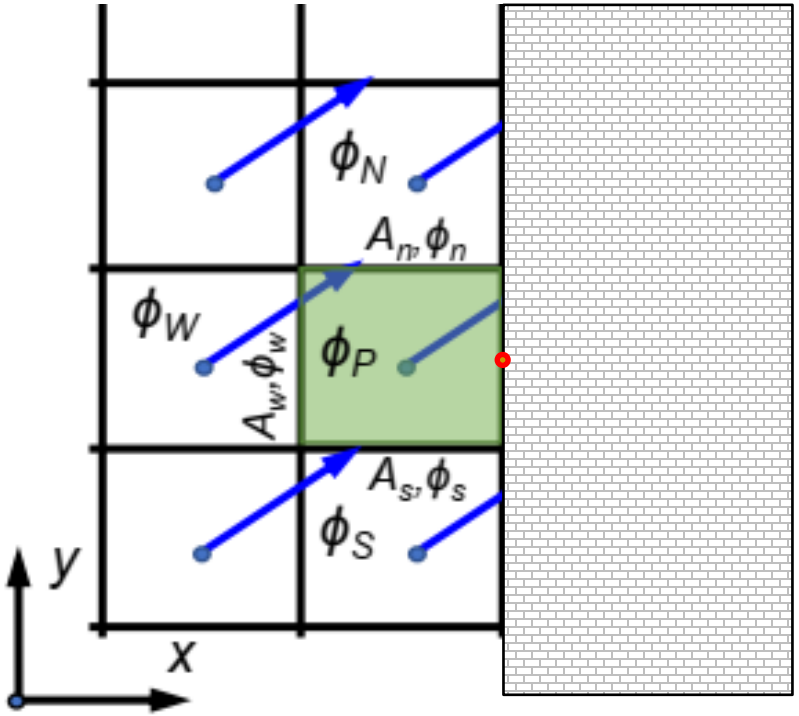
CFD workflow



This module

- Why boundary conditions?
- Types of boundaries conditions
- How to properly set up boundary conditions

Why boundary conditions (BC)?



- To solve the integral calculus of the governing equations, we need the value of ϕ at cell faces, which are found through interpolation.

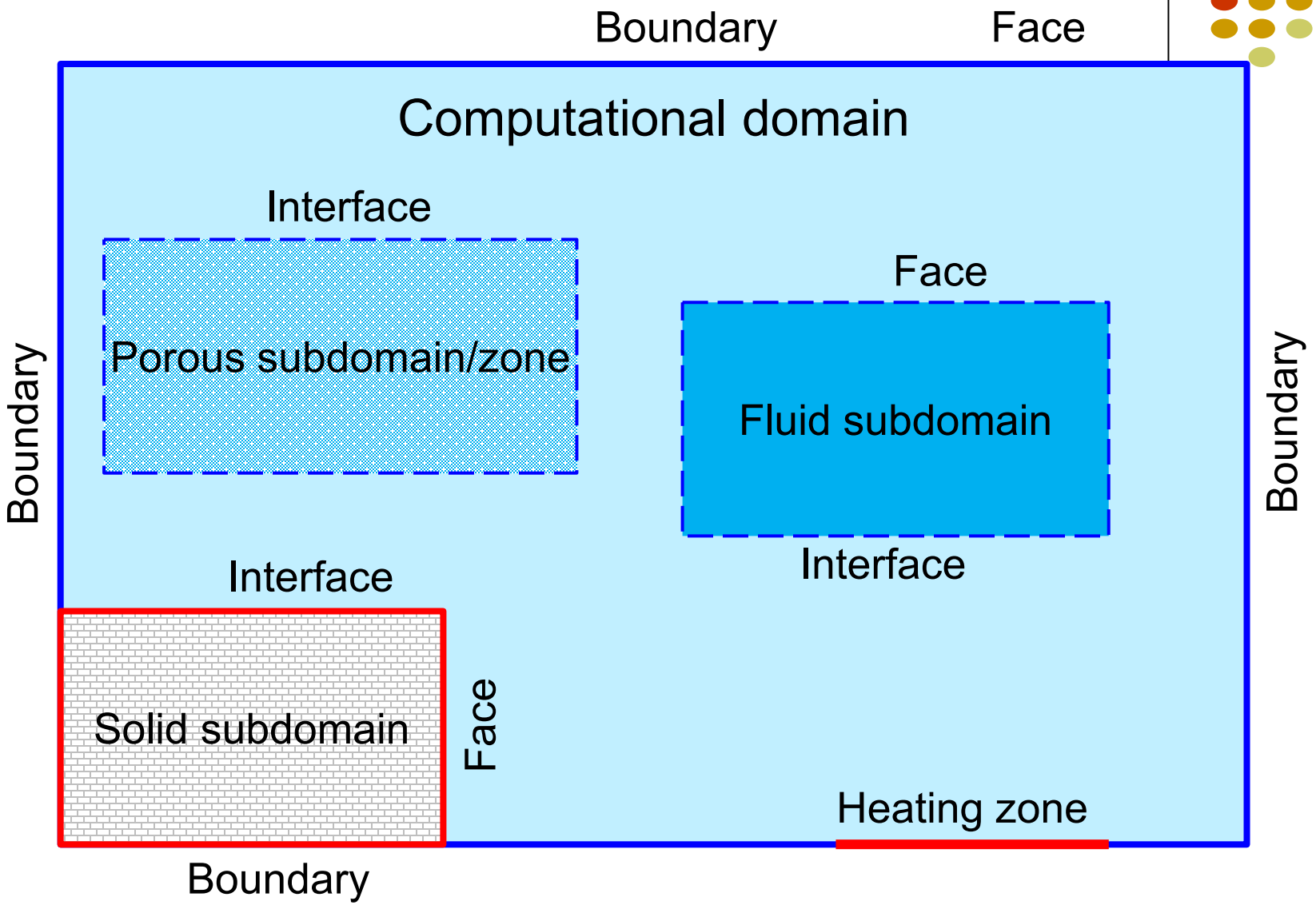
$$\frac{\partial \phi}{\partial t} + \nabla \cdot \left(\bar{U}\phi\right) = \nabla \cdot \left(\Gamma \nabla \phi\right) + S_\phi \quad \Rightarrow$$

$$\begin{aligned} & A_e u_e \phi_e - A_w u_w \phi_w + A_n v_n \phi_n - A_s v_s \phi_s = \\ & \Gamma A_e \left(\phi_E - \phi_P\right) / \delta x_e - \Gamma A_w \left(\phi_P - \phi_W\right) / \delta x_e \\ & + \Gamma A_n \left(\phi_N - \phi_P\right) / \delta y_n - \Gamma A_s \left(\phi_P - \phi_S\right) / \delta y_s + S_P \end{aligned}$$

- At the domain bounding faces where interpolation is prohibited, we must specify the value – this is the **boundary condition**.
- Boundary conditions are a required component of the mathematical model – Iterations need a starting point.
- Boundary conditions also define the overall flow conditions and affect the predictive accuracy.

Terminology

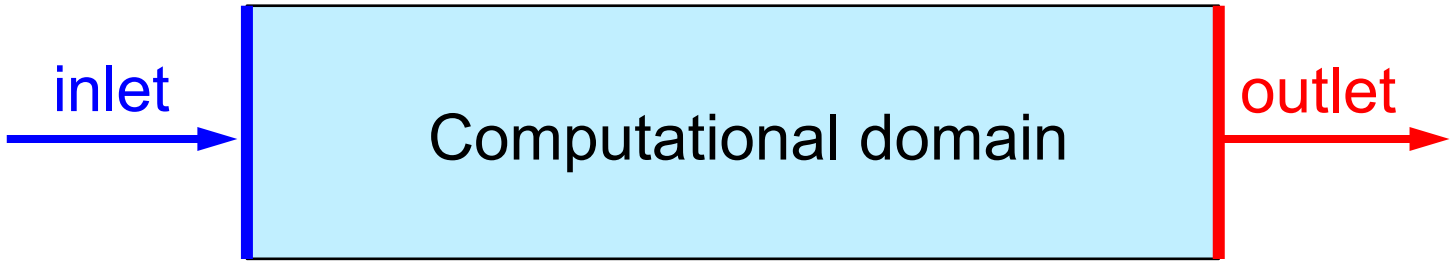
- Domain
- Subdomain
- Zone
- Interface
- Face
- Boundary



Fluid boundary conditions

- Inlet BC: velocity inlet, pressure inlet
- Outlet BC: pressure outlet, outflow
- Wall BC
- Symmetry BC
- Periodic BC

Inlet and outlet BC



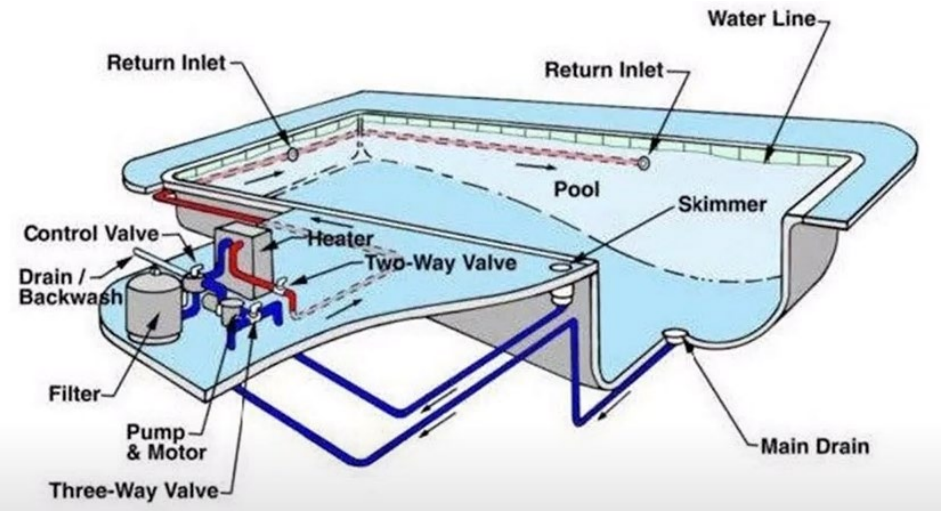
Inlet options

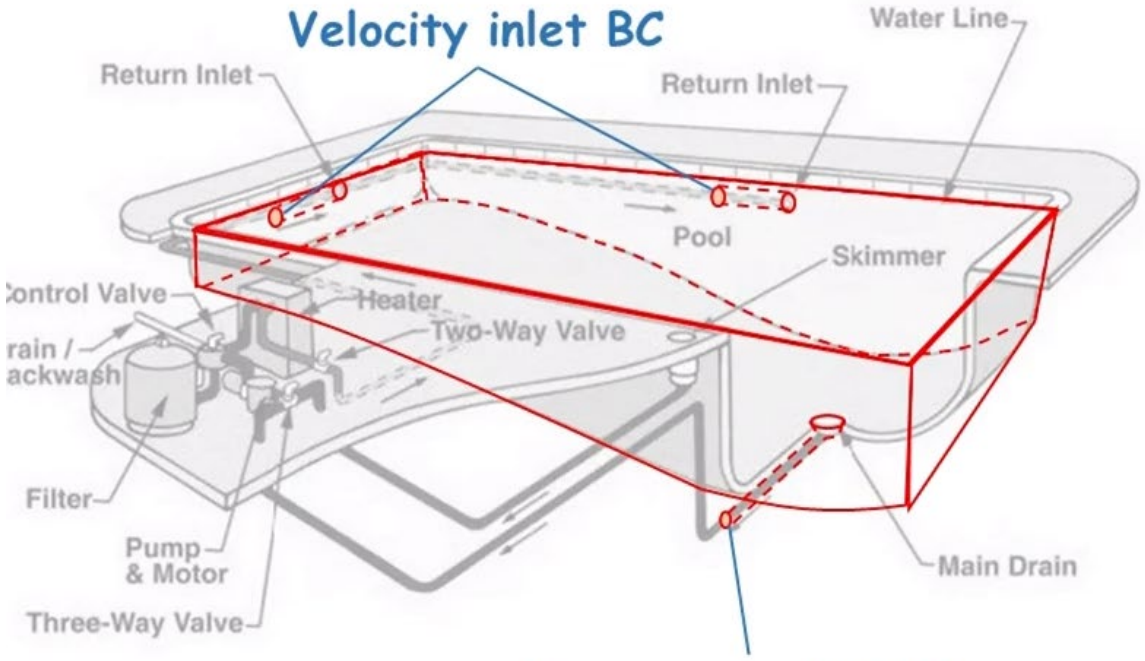
- ❖ Velocity/flow rate inlet
  - Velocity is specified
  - Pressure is calculated
- ❖ Pressure inlet
  - Stagnation pressure is specified
  - Velocity is calculated

Outlet options

- ❖ Pressure outlet
  - Static pressure is specified
  - Velocity is calculated
- ❖ Outflow
  - Velocity and pressure are extrapolated from interior
  - Zero normal gradient
  - Nor for unsteady flow with variable density
  - Not for developing flow at outlet
  - Poor convergence with back flow

Inlet and outlet BC



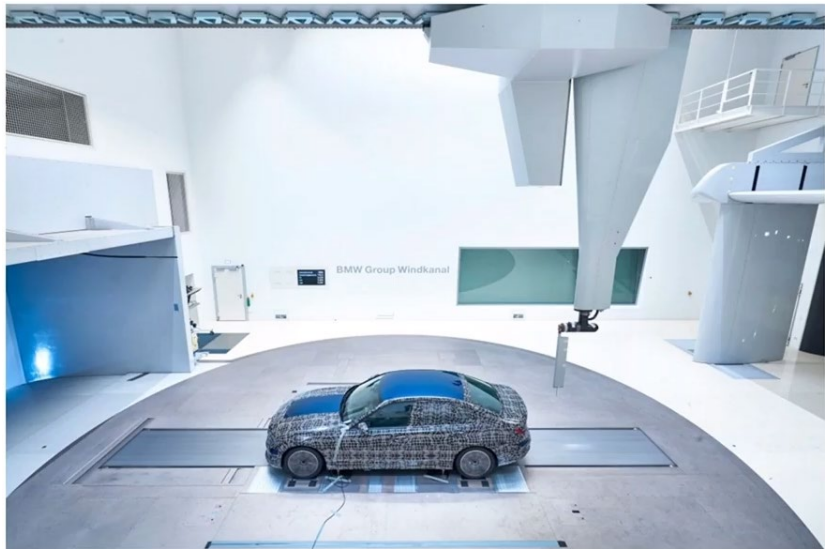


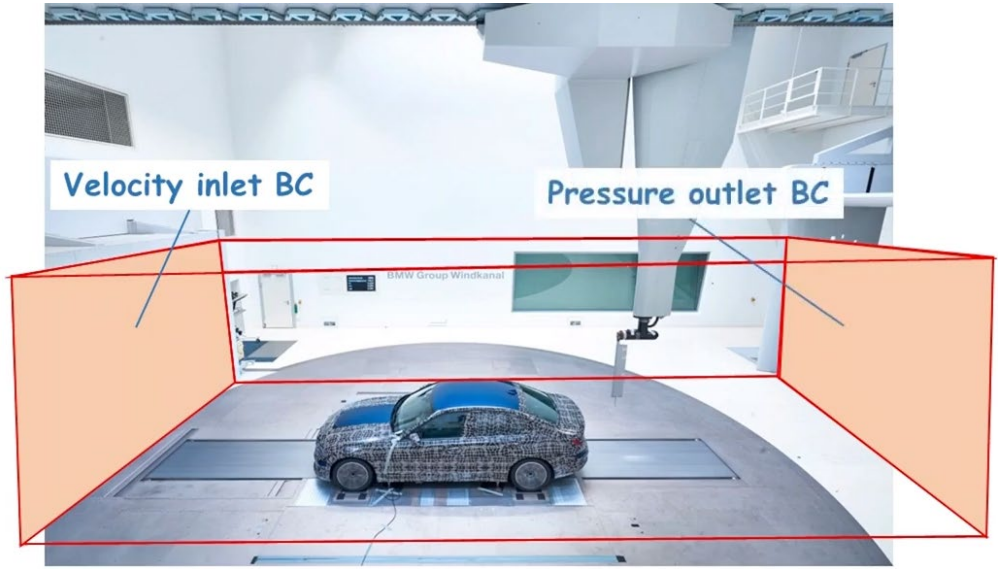
Pressure outlet BC

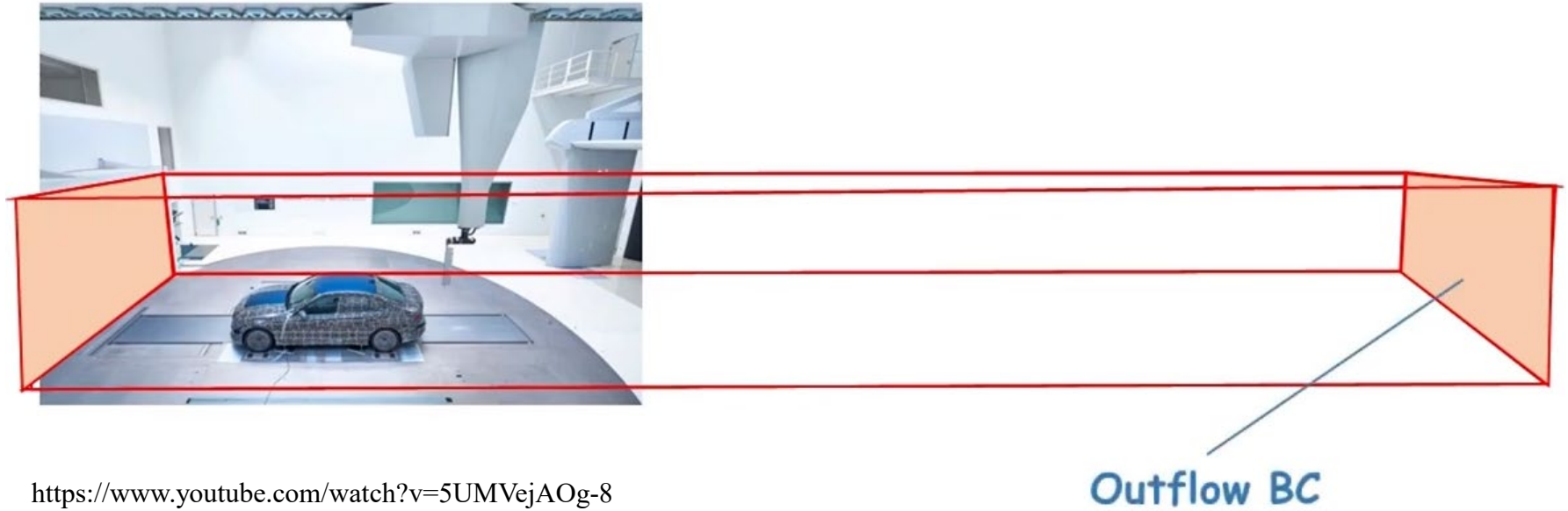
or Outflow BC (if fully developed flow)

https://www.youtube.com/watch?v=5UMVejAOg-8

Inlet and outlet BC







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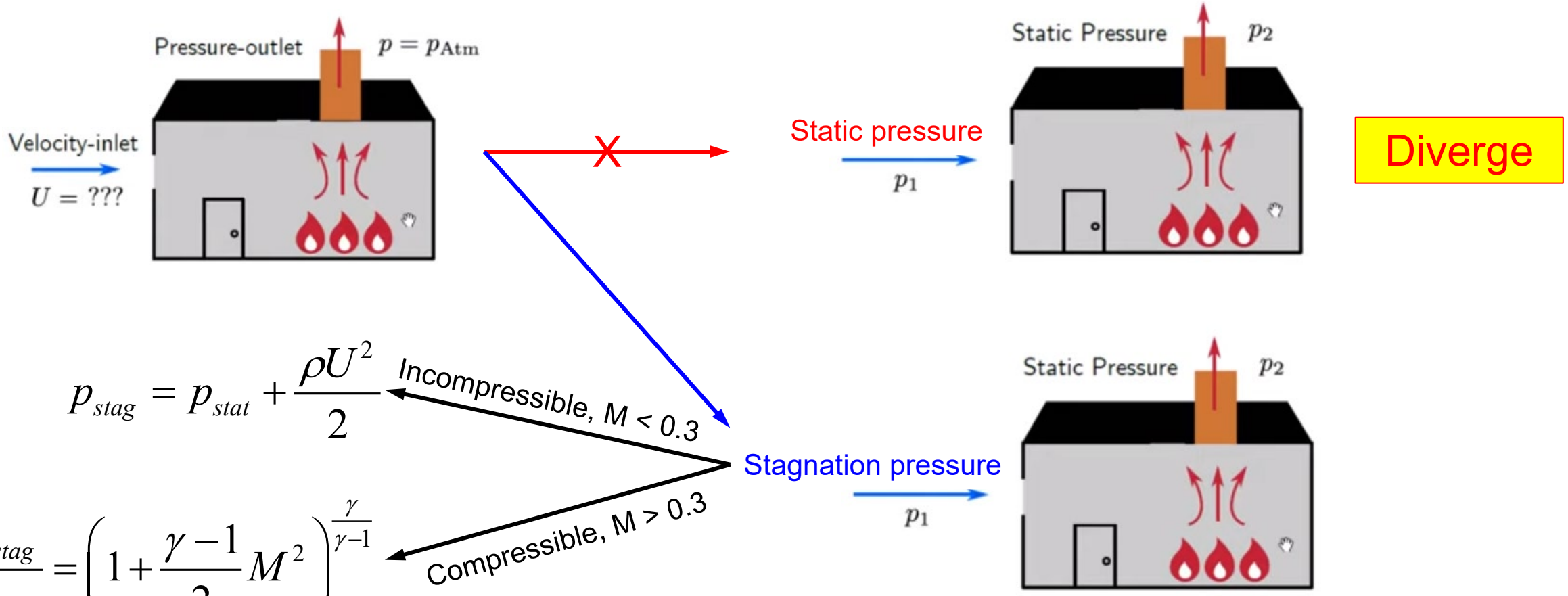
Pressure inlet

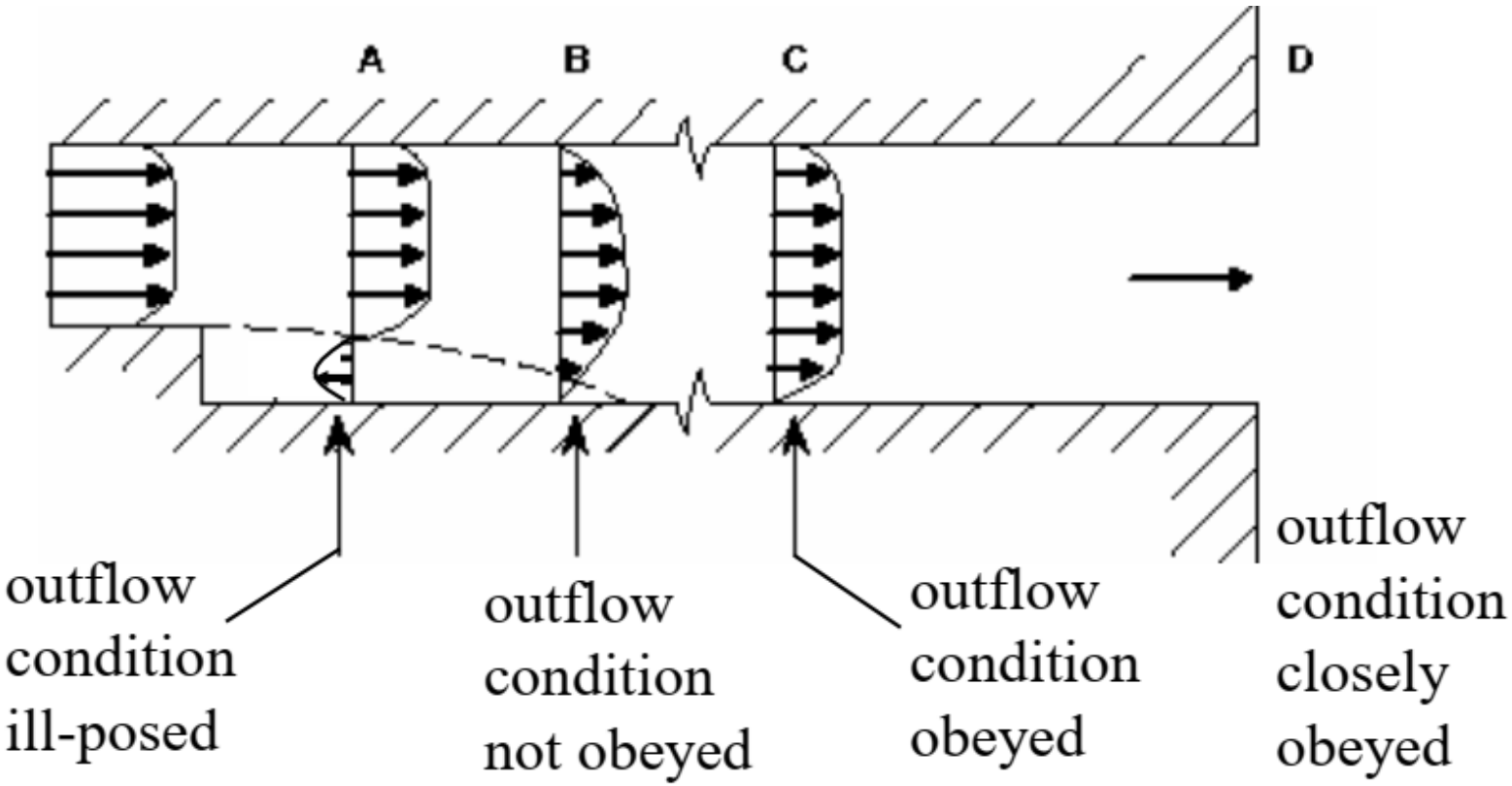
❖ What if you don't know the velocity or flow rate?



$$p_{stag} = p_{stat} + \frac{\rho U^2}{2}$$

$$\frac{p_{stag}}{p_{stat}} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{\gamma - 1}}$$

Outlet

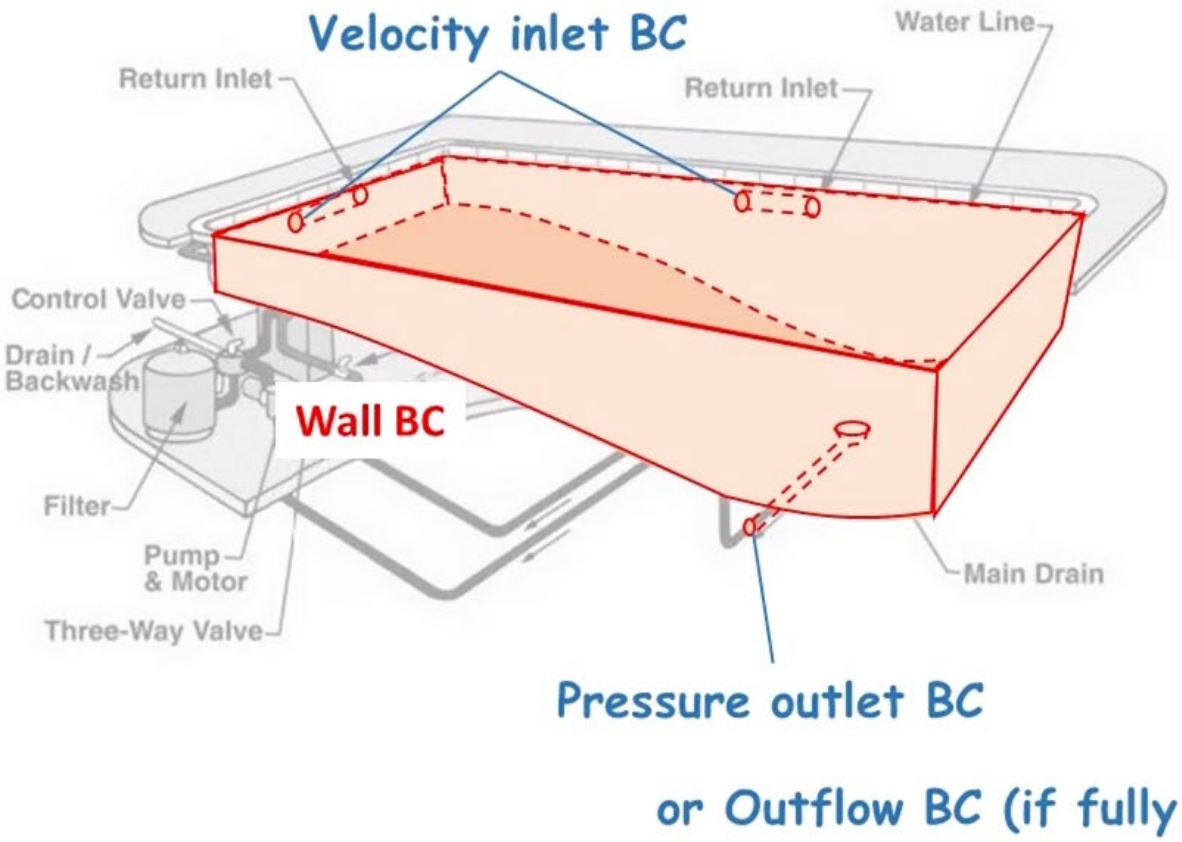


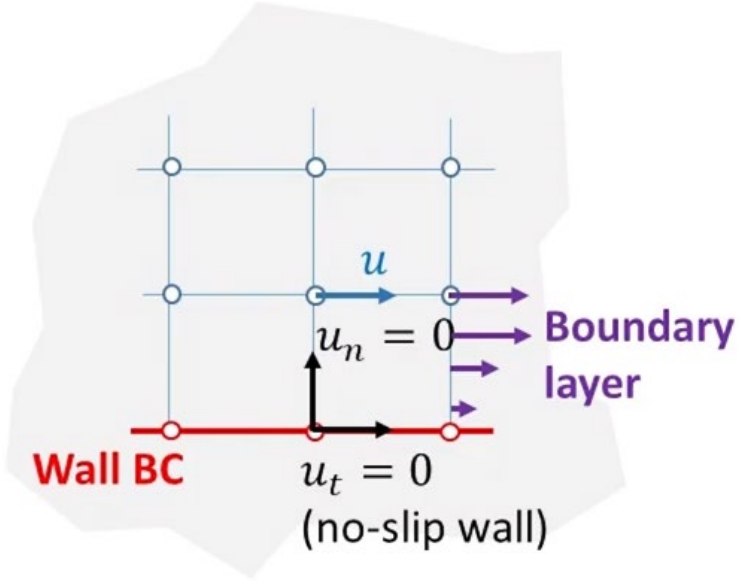
- How to specify boundary conditions effectively in order to reduce errors?
- Numerical stability

Wall BC

- No mass flow across wall boundaries
- Heat transfer is allowed
- With/without viscous effects
- Stationary/moving

Wall BC





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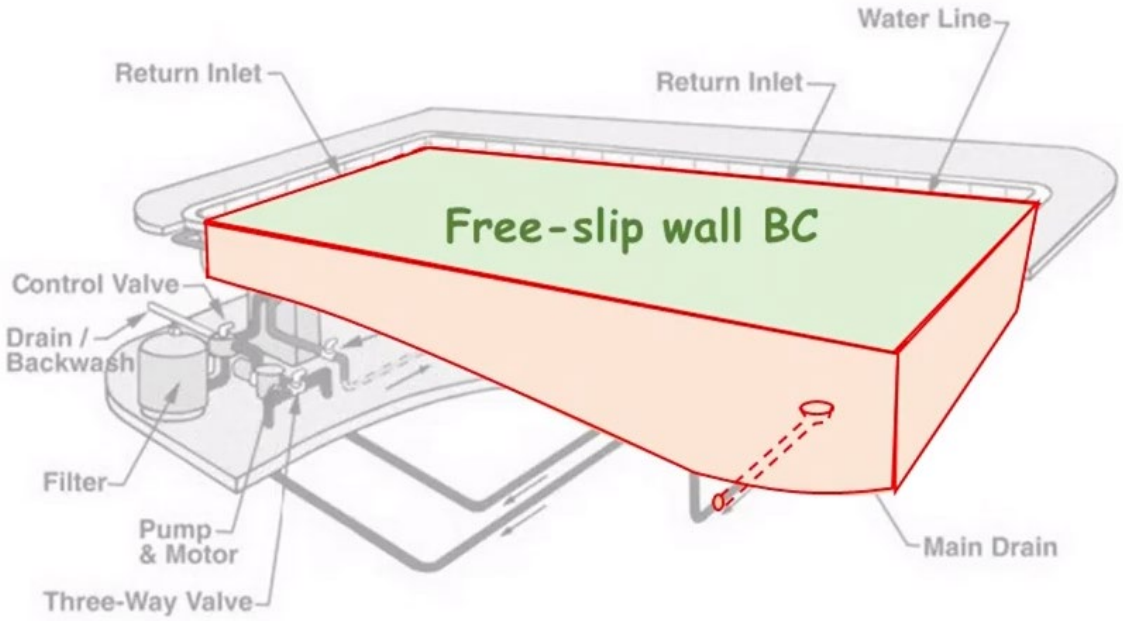
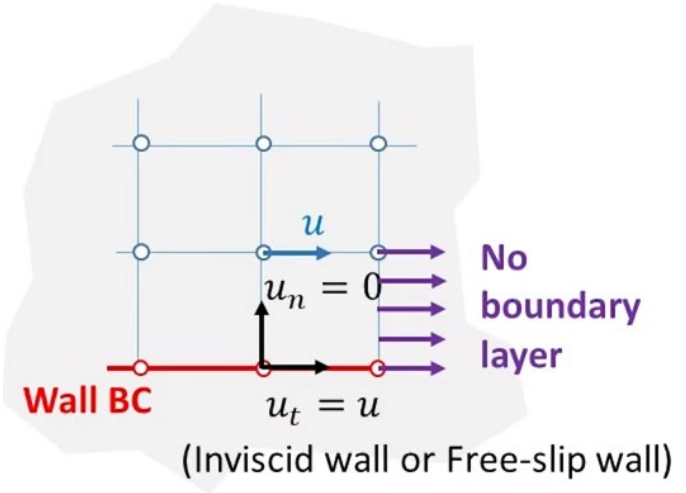
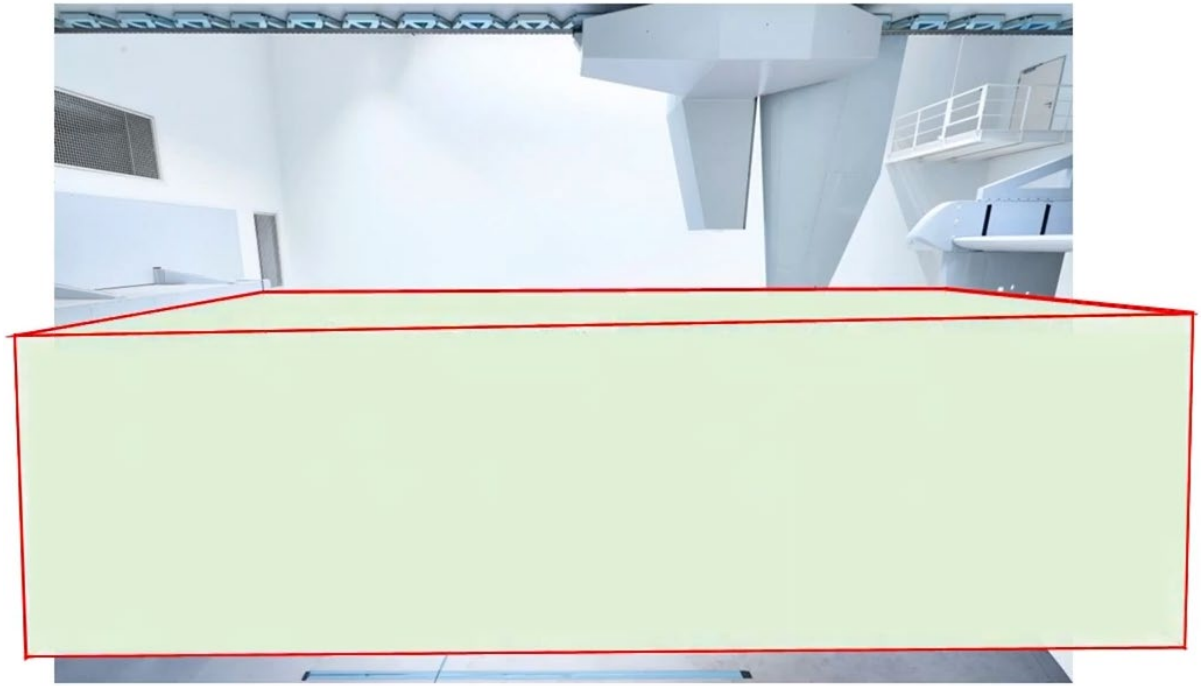
Free-slip wall BC







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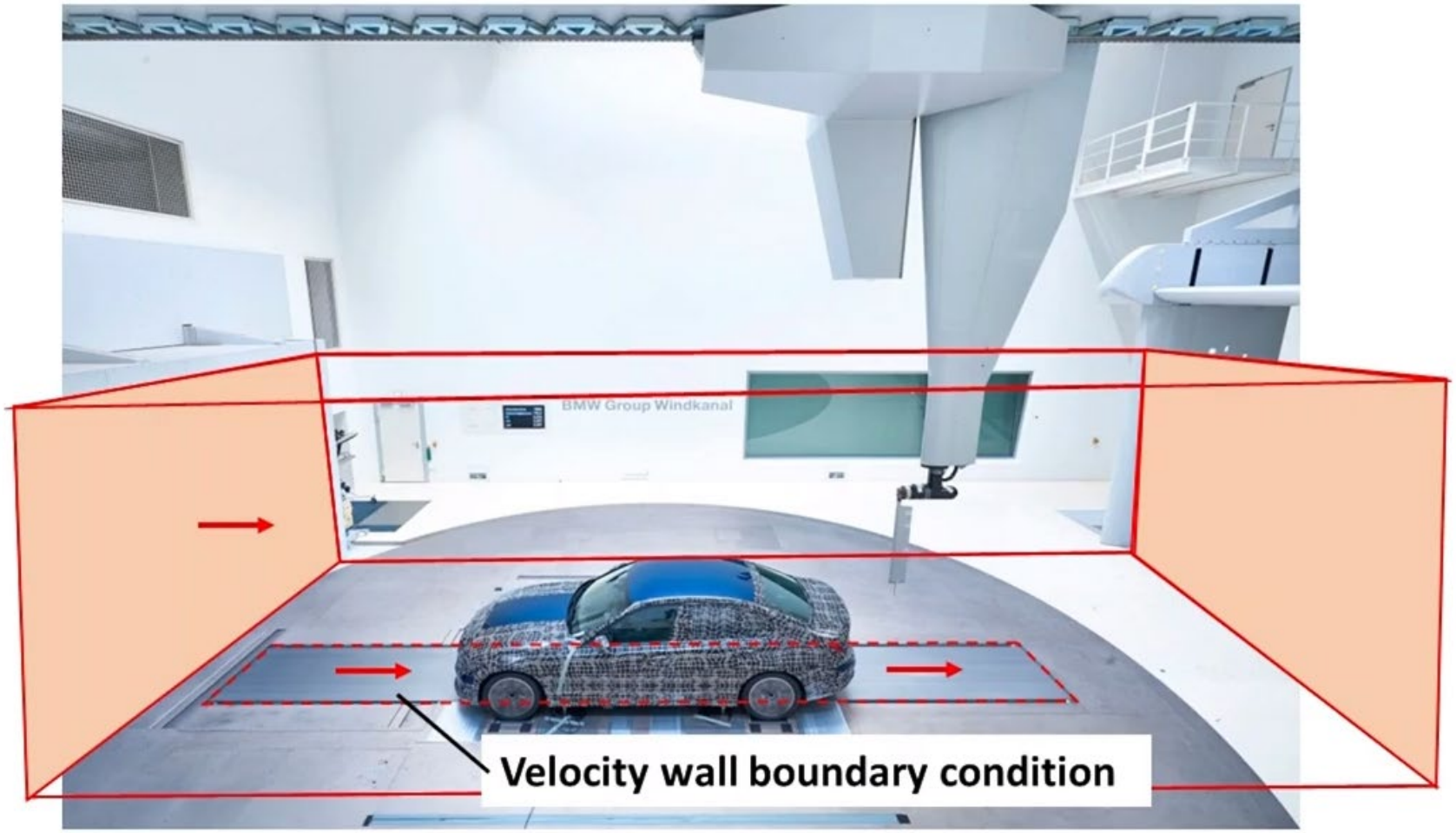
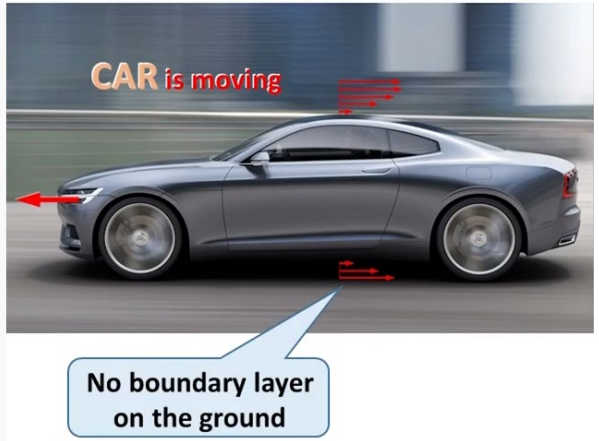
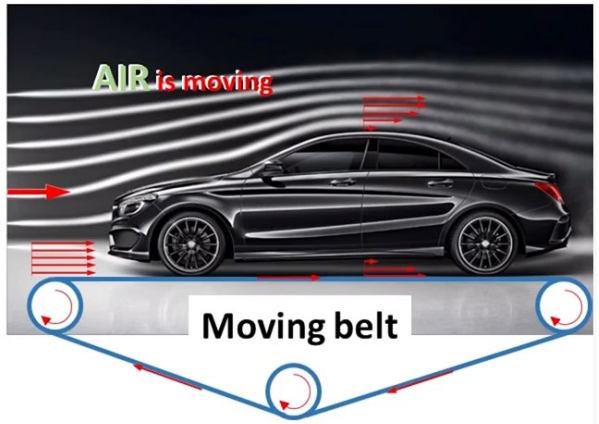
Moving wall BC



Real driving



Wind tunnel



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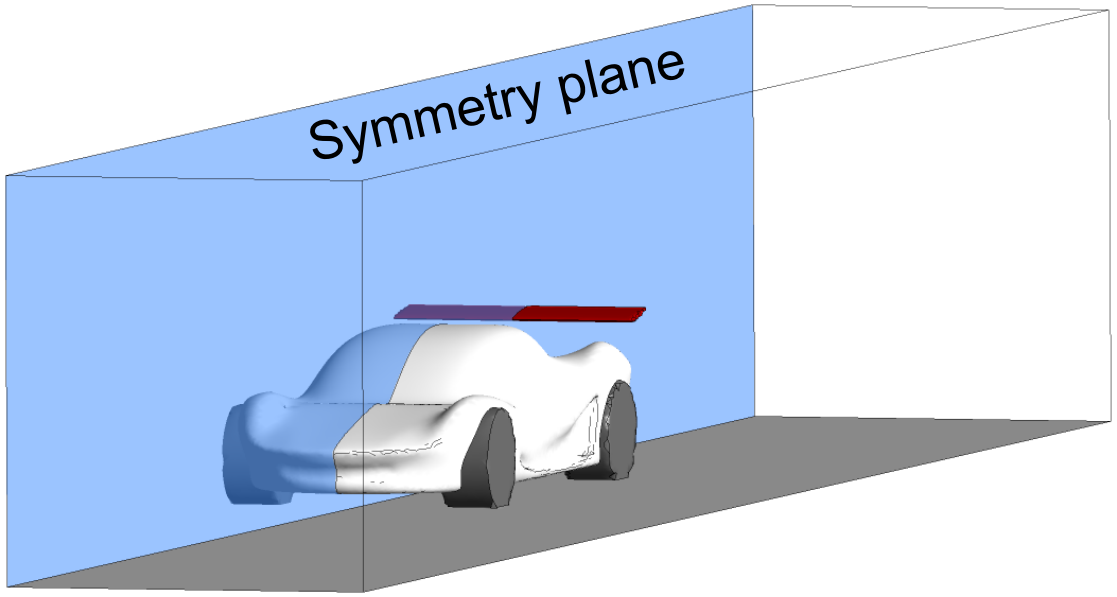
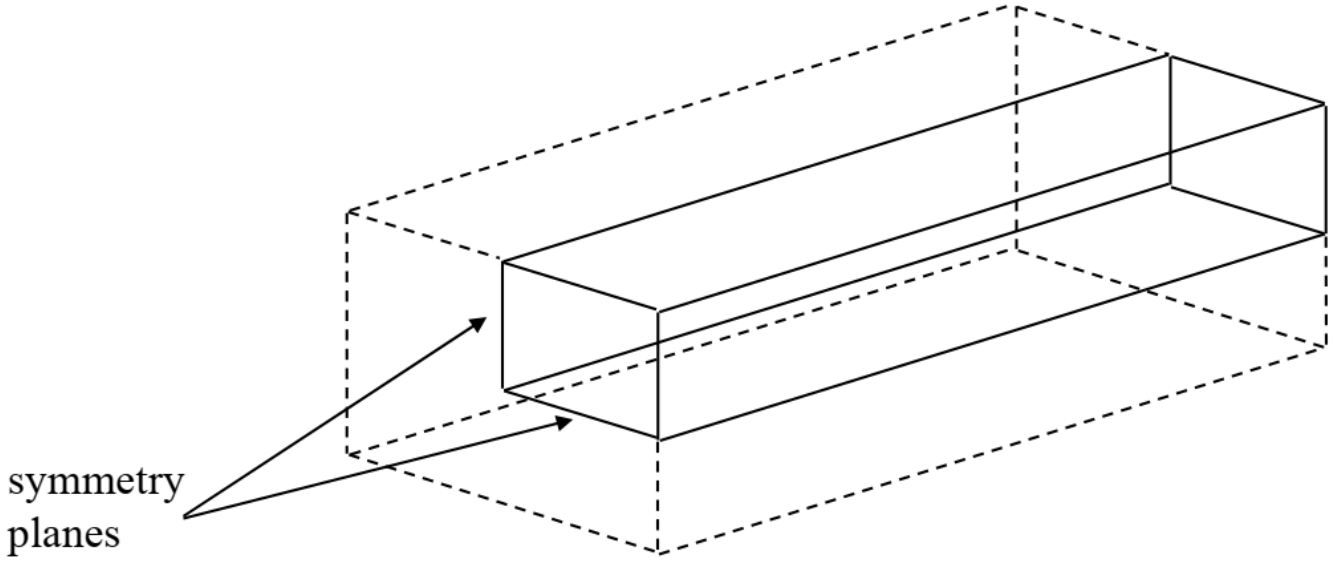
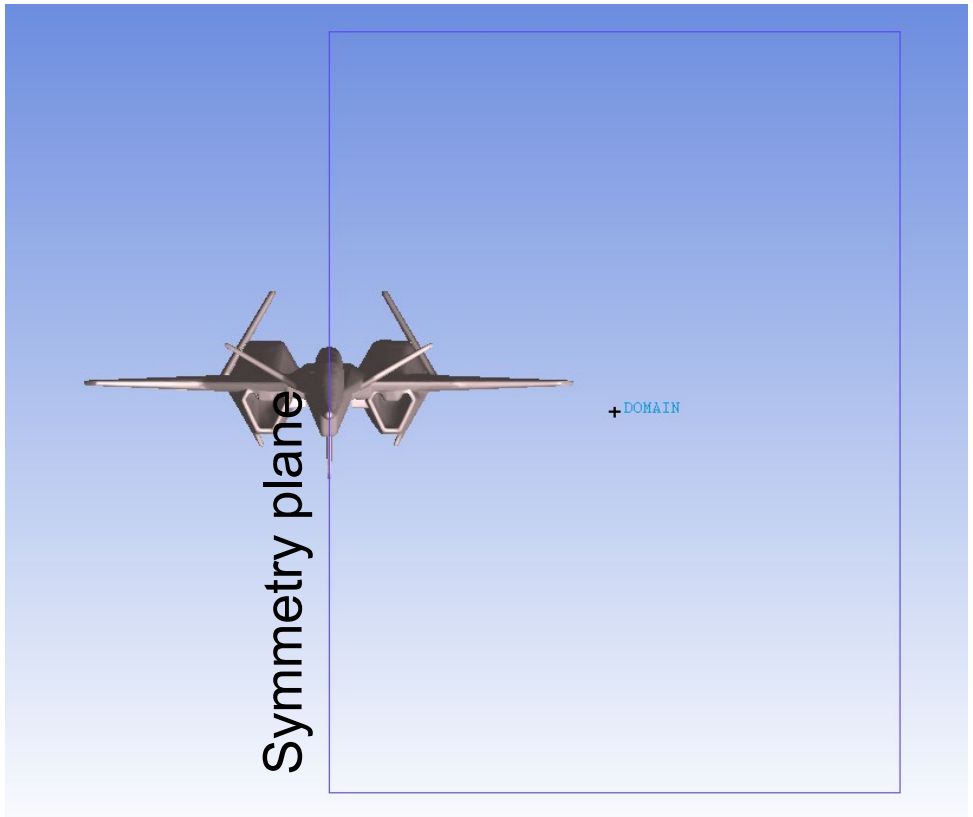
Symmetry BC

- Both the flow field and geometry are symmetrical
- Reduced computational cost
- Normal gradient is zero

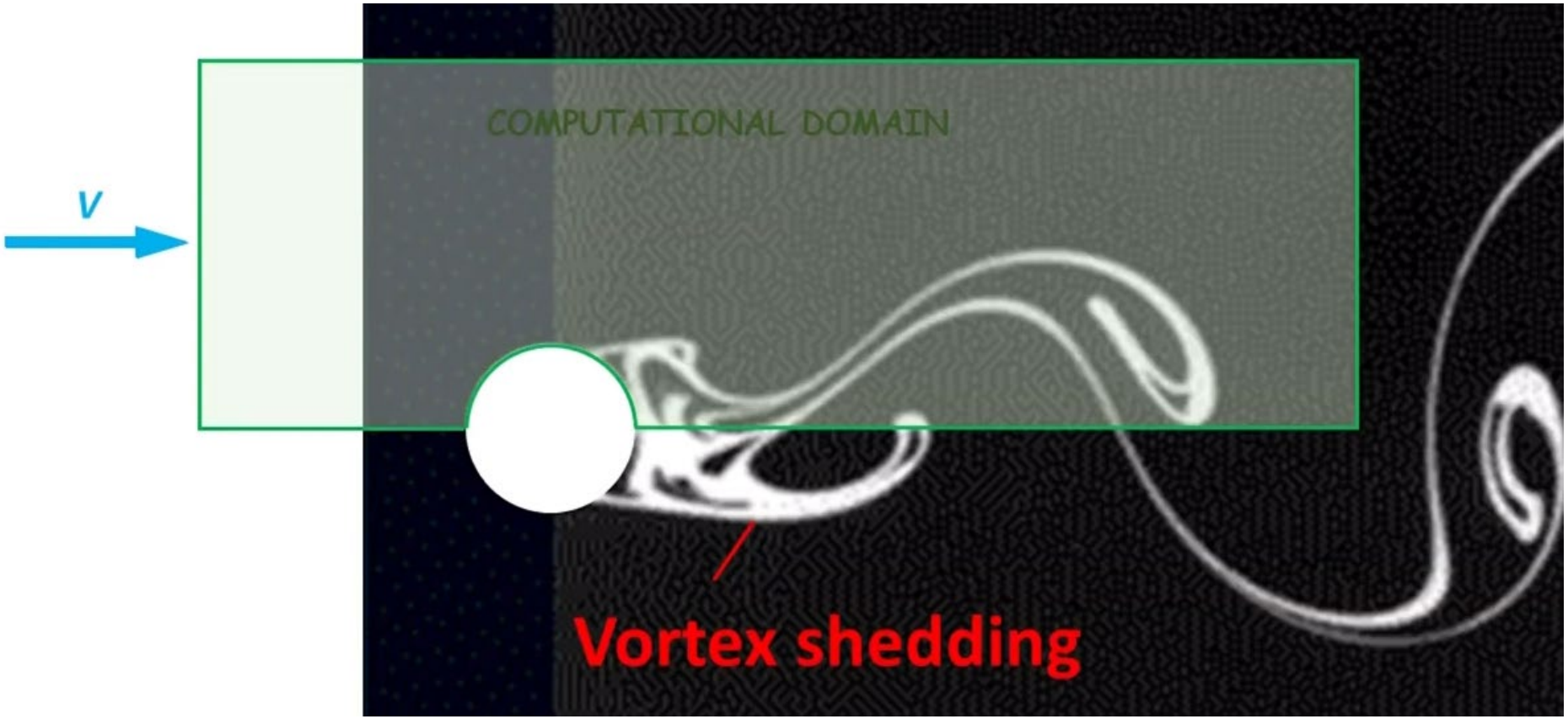






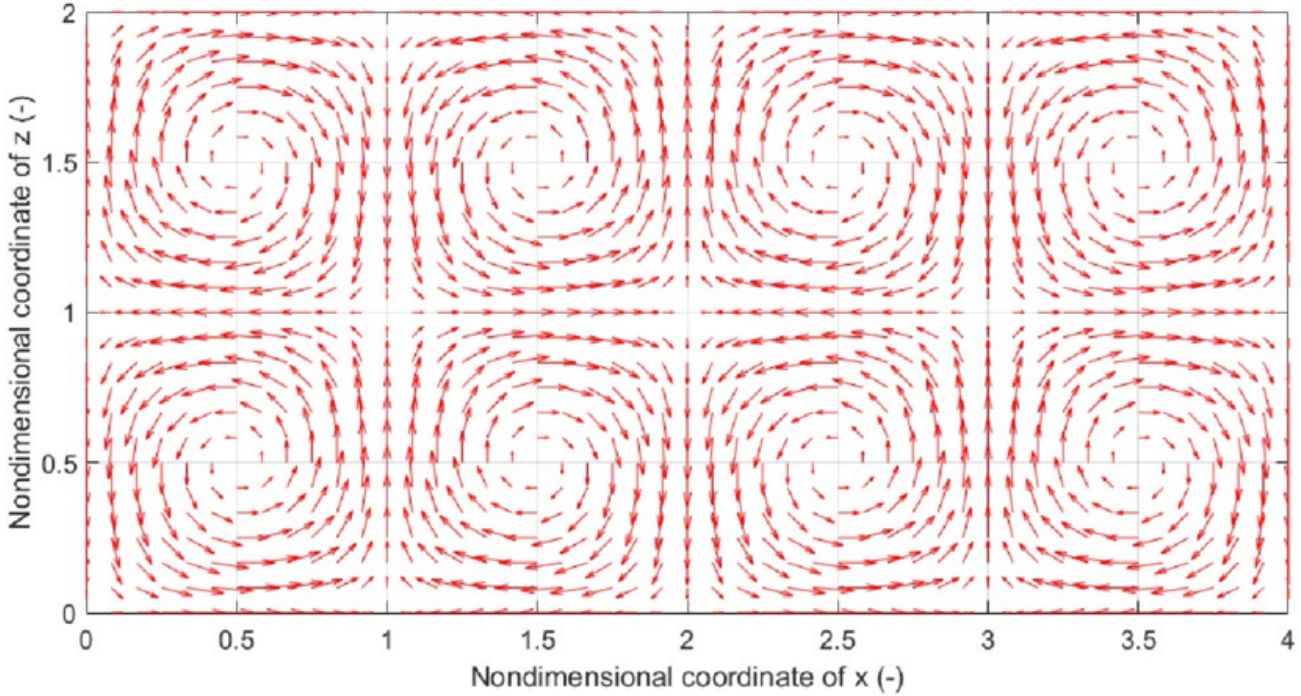
Symmetry BC

- Steady-state: symmetrical
- Transient: Asymmetrical

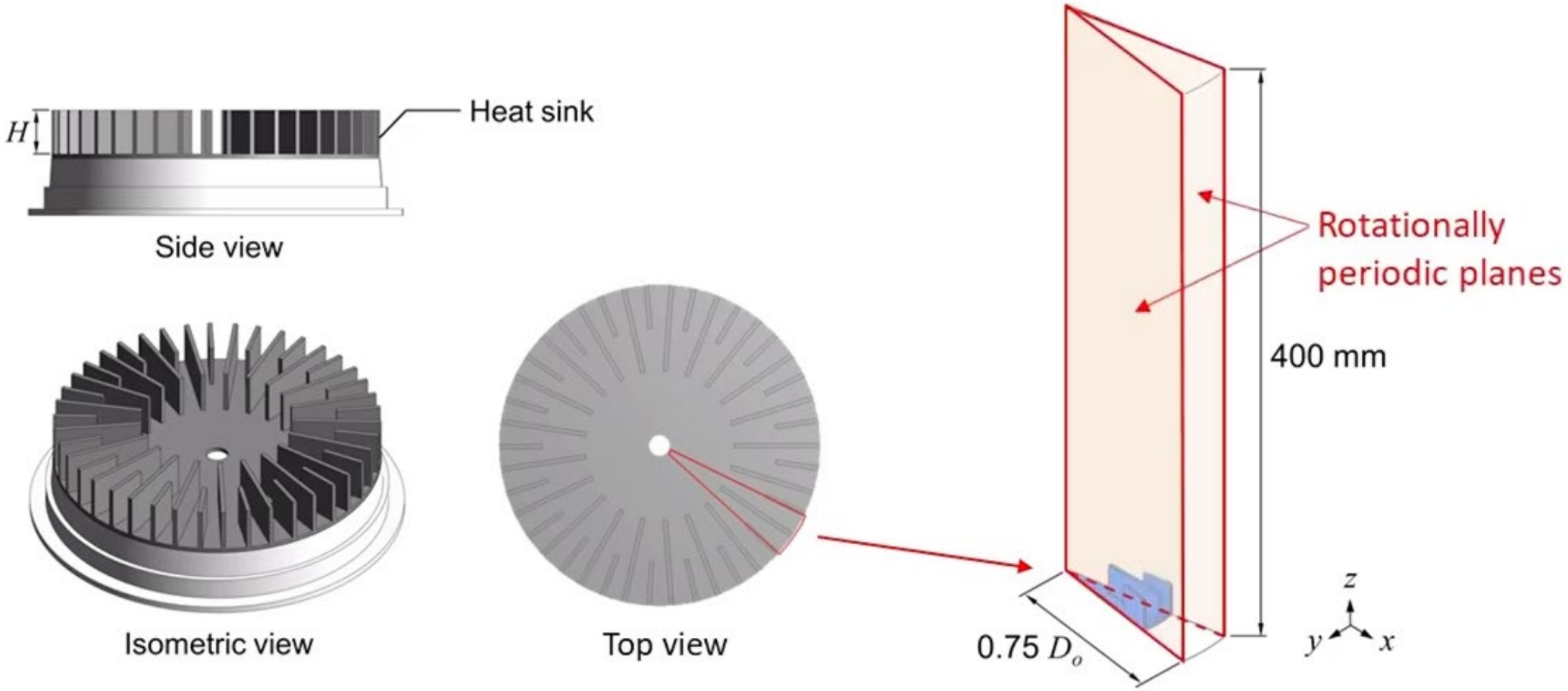


Periodic BC

- Flow field repeats periodically
- Translationally periodic
- Rotationally periodic



Applying a periodic BC



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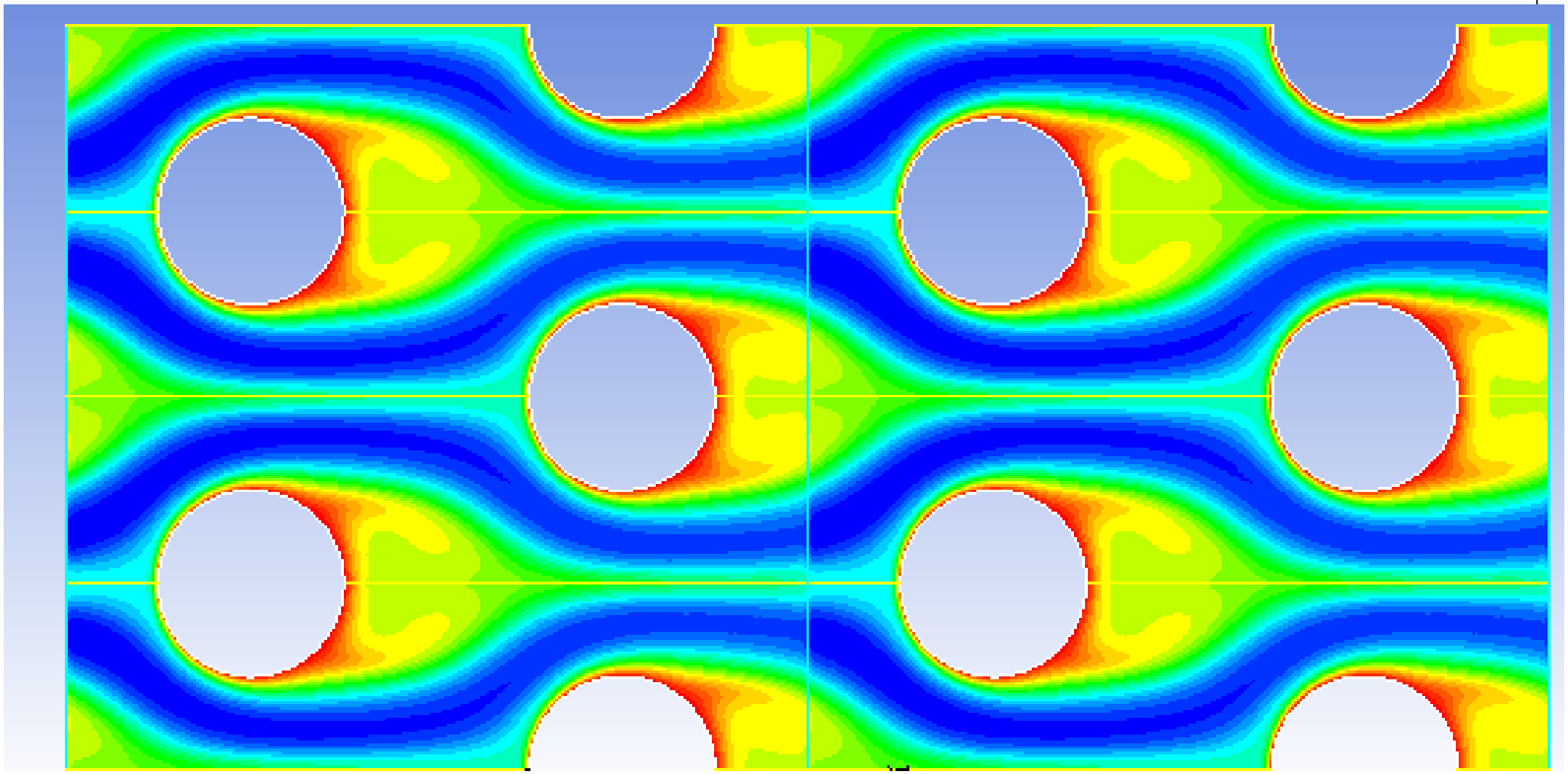
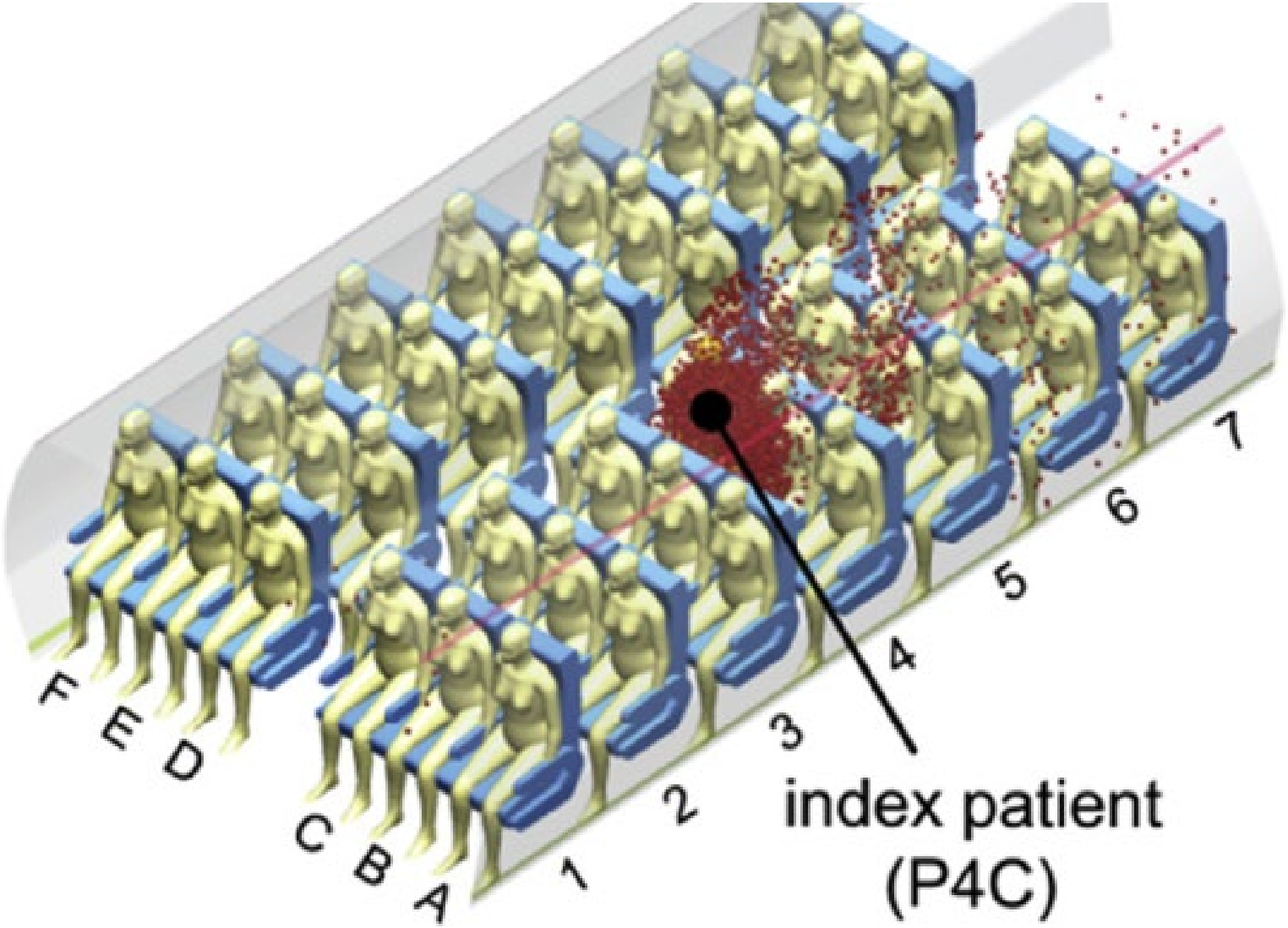
What BCs are applicable?



https://flowwithhatef.wordpress.com/2017/10/12/137/

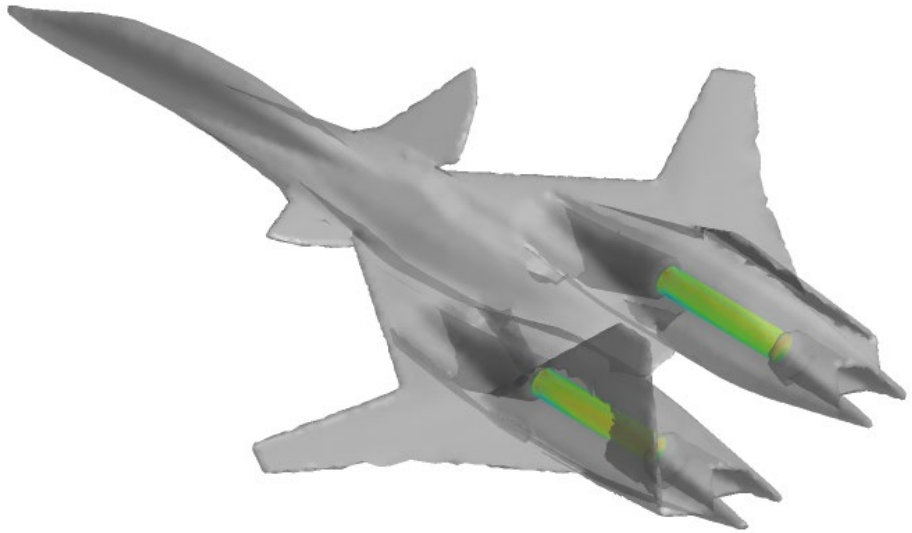
What BCs are applicable?

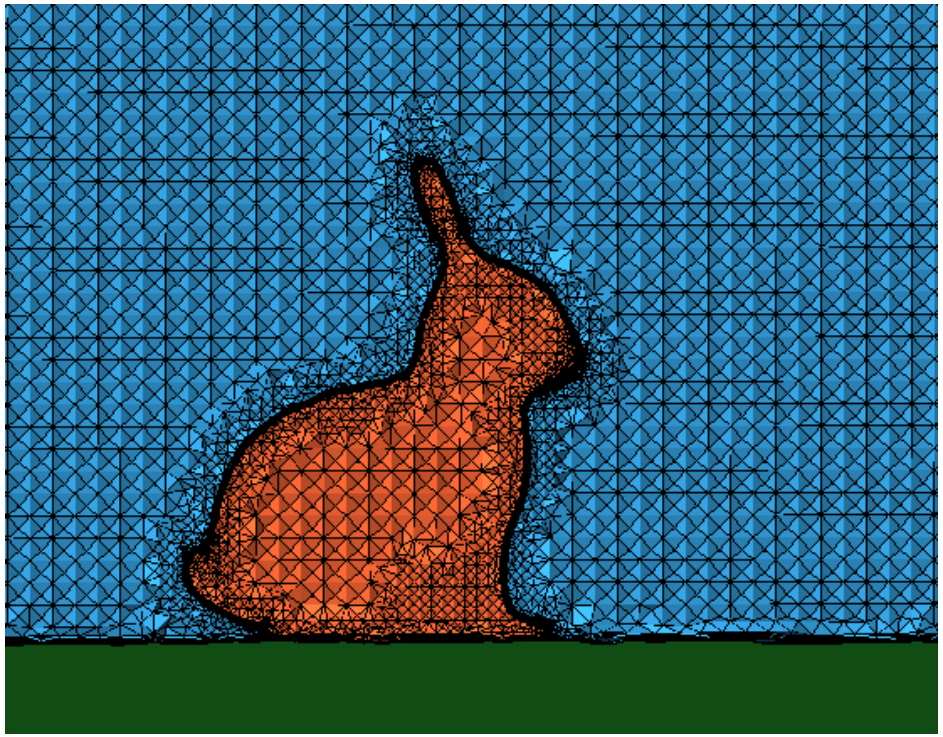


Subdomains/3D zones

- Fluid zone: Flow equations are solved
- Solid zone: No flow equations. Thermal conduction equations may be solved
- Porous media zone: Special type of fluid zone

❖ A good approach to approximation – using source terms





Q&A