Mini Project Review 2

STUDYING THE VENTILATION PATTERNS IN A COVID-19 MULTI-PATIENT WARD USING CFD

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02 CASE SETUP

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1. Recap

1.1 1st Review Recap

We had discussed:

- Literature Survey
- Problem Statement and Design Considerations
- CAD model (generated in FreeCAD)
- Meshing process (done through Gmsh)
- Our Base Case

1.2 Questions from 1st Review

1. **What happens to the viri particles after they get out through the outlet?**

   The US EPA suggests using HEPA filters combined with CADR rating systems to monitor their filtration systems. Similarly, the UK conducted studies using UV sterilization techniques. Through these techniques, we can ensure that 99.9% of all viral particles are removed. Unfortunately, most of the research in this area is still being peer reviewed, so we can't say for sure which strategy is the best.

2. **Was there any reason for us exporting CAD models in .STL?**

   STL file format is widely used because the encoding minimizes disk space used. But STEP files are typically much easier to edit due to the STEP file type being designed specifically for CAD editing purposes. And since our design iteration process required us editing our CAD models frequently, we shifted over from .STL to .STEP

2. Case Setup

2.1 Properties and Assumptions

Properties :

- Kinematic viscosity = $15.6 * 10^{-6}$ m^2/s
- Room Temperature = 26^o C
- Density = 1.184 kg / m^3

Assumptions :

- Incompressible, unsteady, laminar flow
- Air behaves as an ideal gas

2.2 Equations

Continuity equation :

$$\frac{\partial \rho}{\partial t} + \overrightarrow{\nabla} \cdot (\rho \overrightarrow{u}) = 0$$

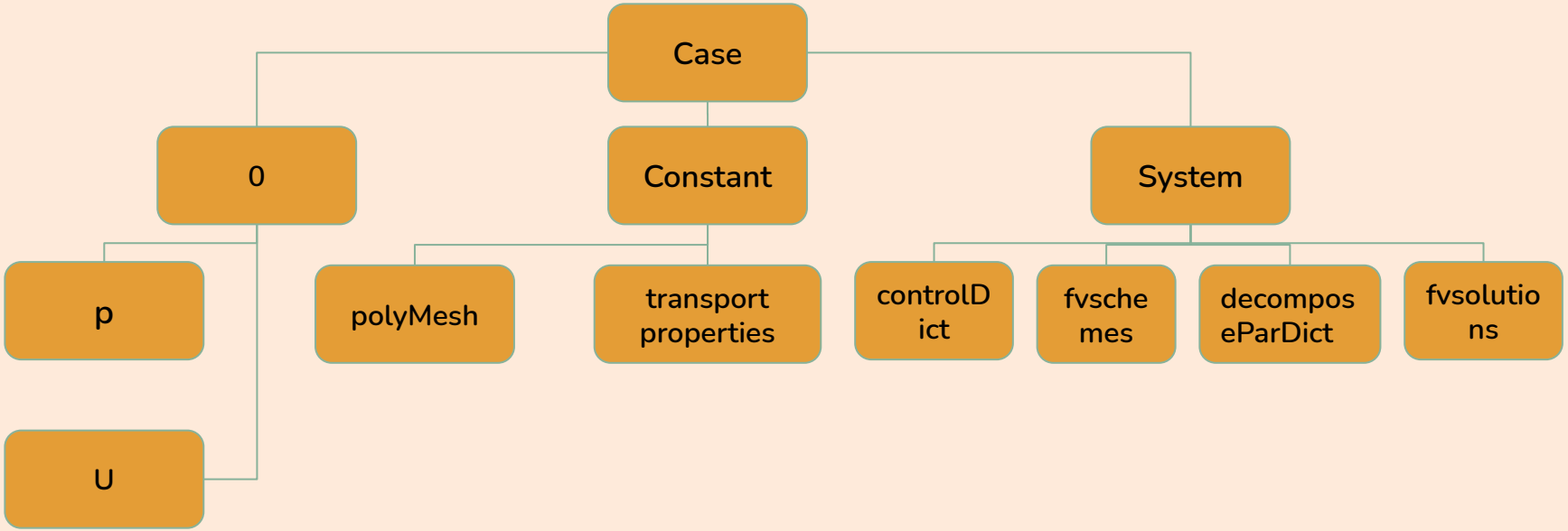
Navier-Stokes equation :

$$\rho[\frac{\partial \overrightarrow{v}}{\partial t} + \overrightarrow{v} \cdot \overrightarrow{\nabla v}] = -\overrightarrow{\nabla p} + \overrightarrow{\nabla} \cdot \overline{\overline{\tau}} + \rho \overrightarrow{f}$$

2.3 Boundary Conditions

SURFACE	BOUNDARY CONDITIONS	
	Velocity (m/s)	Kinematic Pressure (m^2/s^2)
Main inlet	(-5.186, 0, 0)	Zero Gradient
Branch inlet	(0, 0, -5.186)	Zero Gradient
Main outlet	Zero Gradient	Uniform 0
Branch outlet	Zero Gradient	Uniform 0
Walls	No Slip	Zero Gradient
Surfaces	No Slip	Zero Gradient

2.4 Configuration



3. Simulation Results

3.1 Cases We're Discussing

1_inlet_1_outlet

- This is a test case that we used to check if our pipeline works as intended.

2_branch_pair_shifted

- Shifted the beds down the room by 5 feet and replaced the "main" ducts with two pairs of ducts running across the room horizontally.

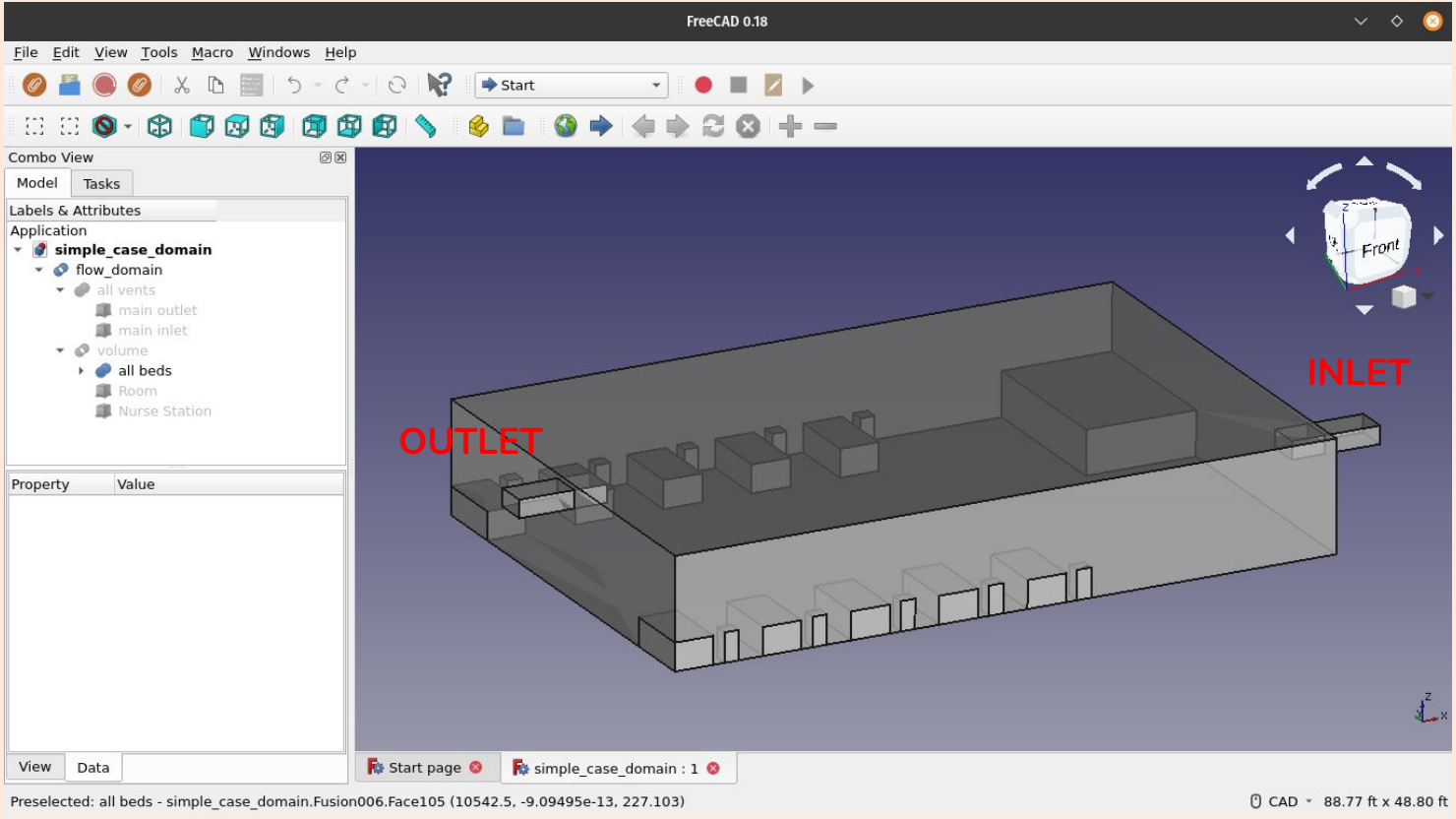
3_wall_4_ceiling

- Installed two wall mounted inlets, while also removing one of the ceiling mounted inlets in an attempt to improve flow near nurse station.

3_wall_5_ceiling

- Added an extra outlet vent to the previous case see what kind of effect it would have on the flow.

3.2 1_inlet_1_outlet



ParaView 5.6.0 64-bit

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Properties Information

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Maximum Number Of Labels 100

View (Render View)

Axes Grid Edit

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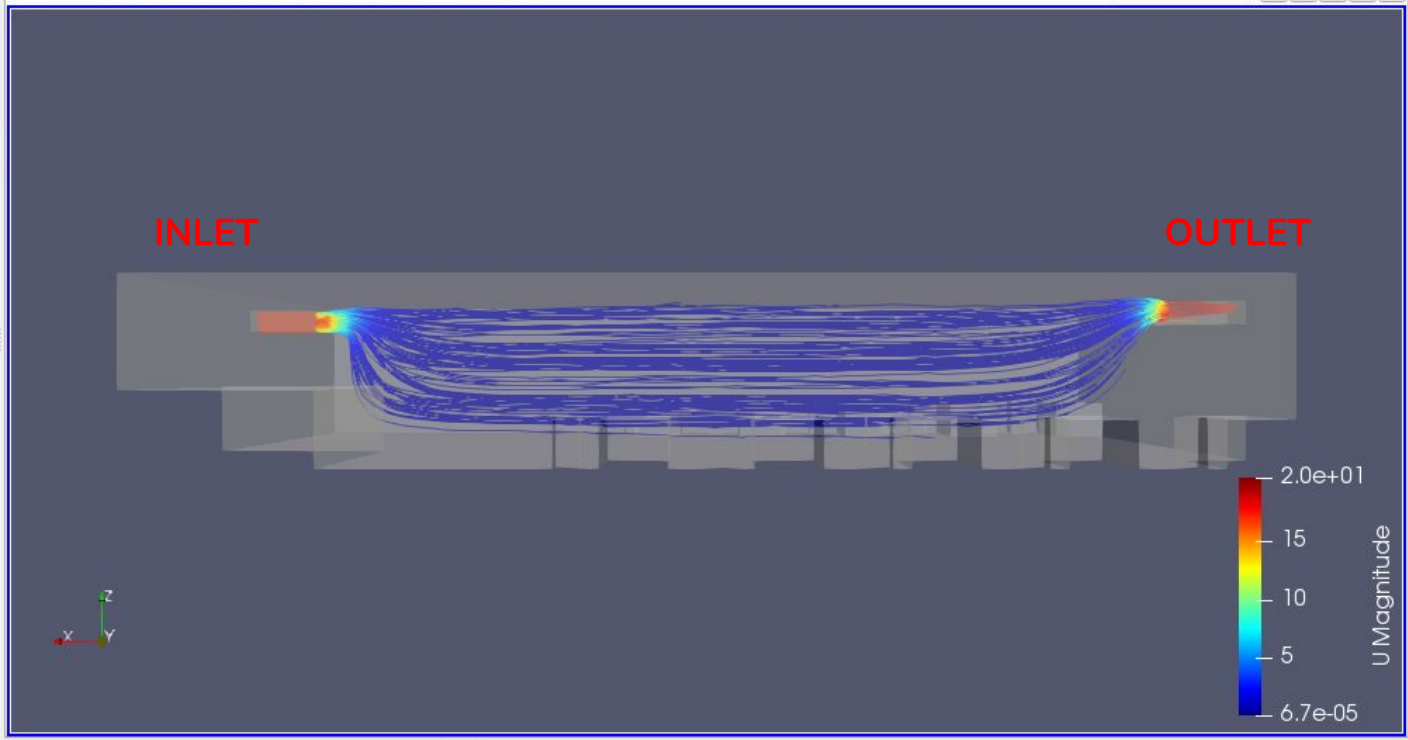

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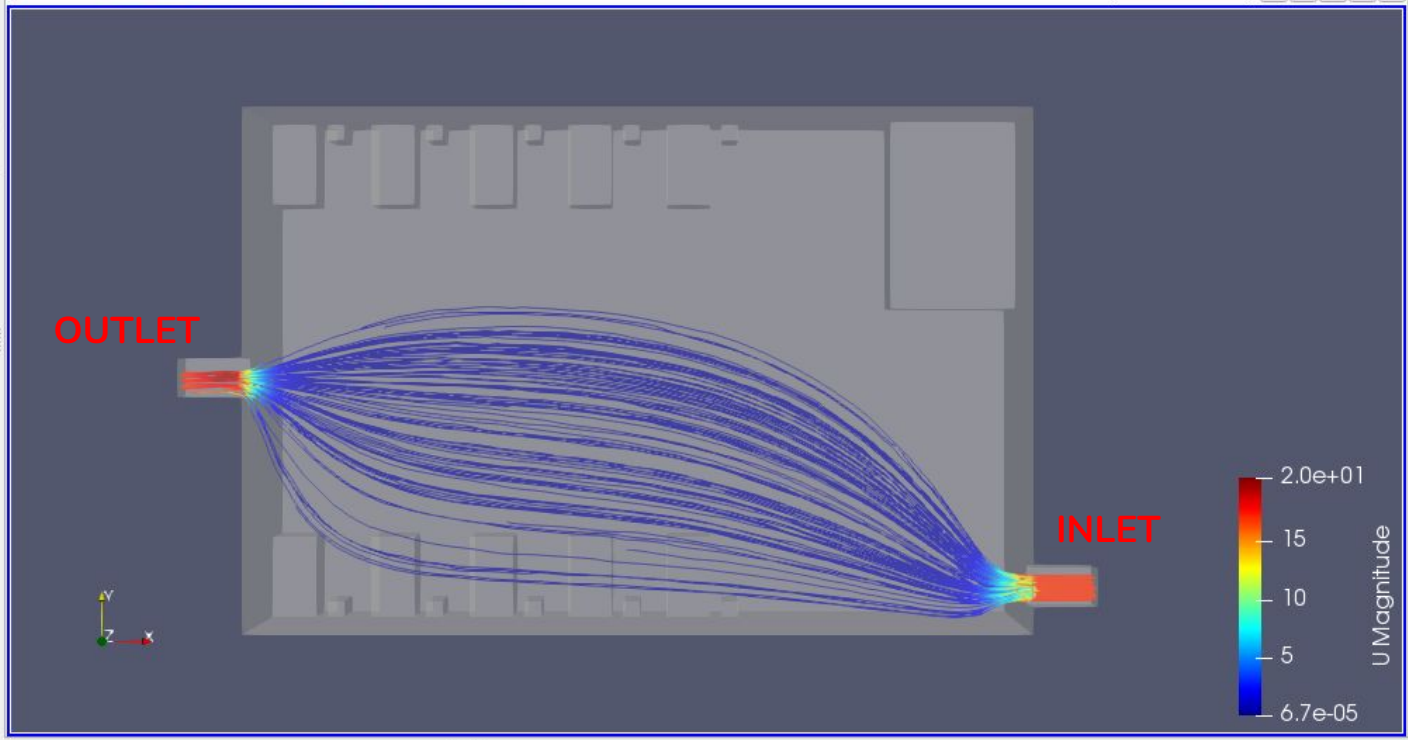


3.2 1_inlet_1_outlet

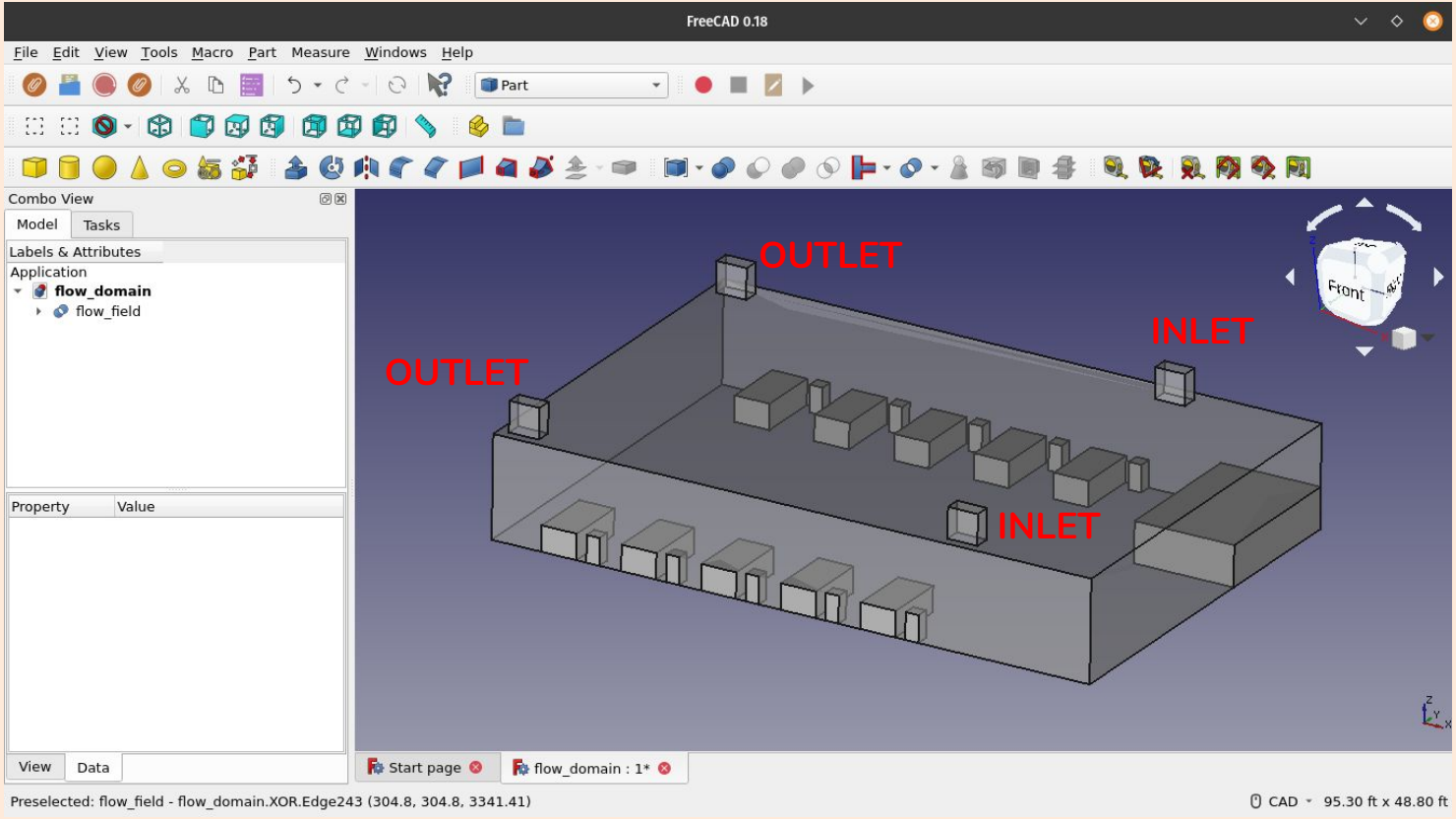
Key Takeaways:

- The procedure for running simulations (from CAD to post processing) is established.
- There is little or no flow in most of the room.

Next steps:

- See if adding ceiling-mounted vents improves flow.
- Move beds by a few feet to ensure they get ventilated.

3.3 2_branch_pair_shifted



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Hidden Line Removal

Camera Parallel Projection

Layout #1 +

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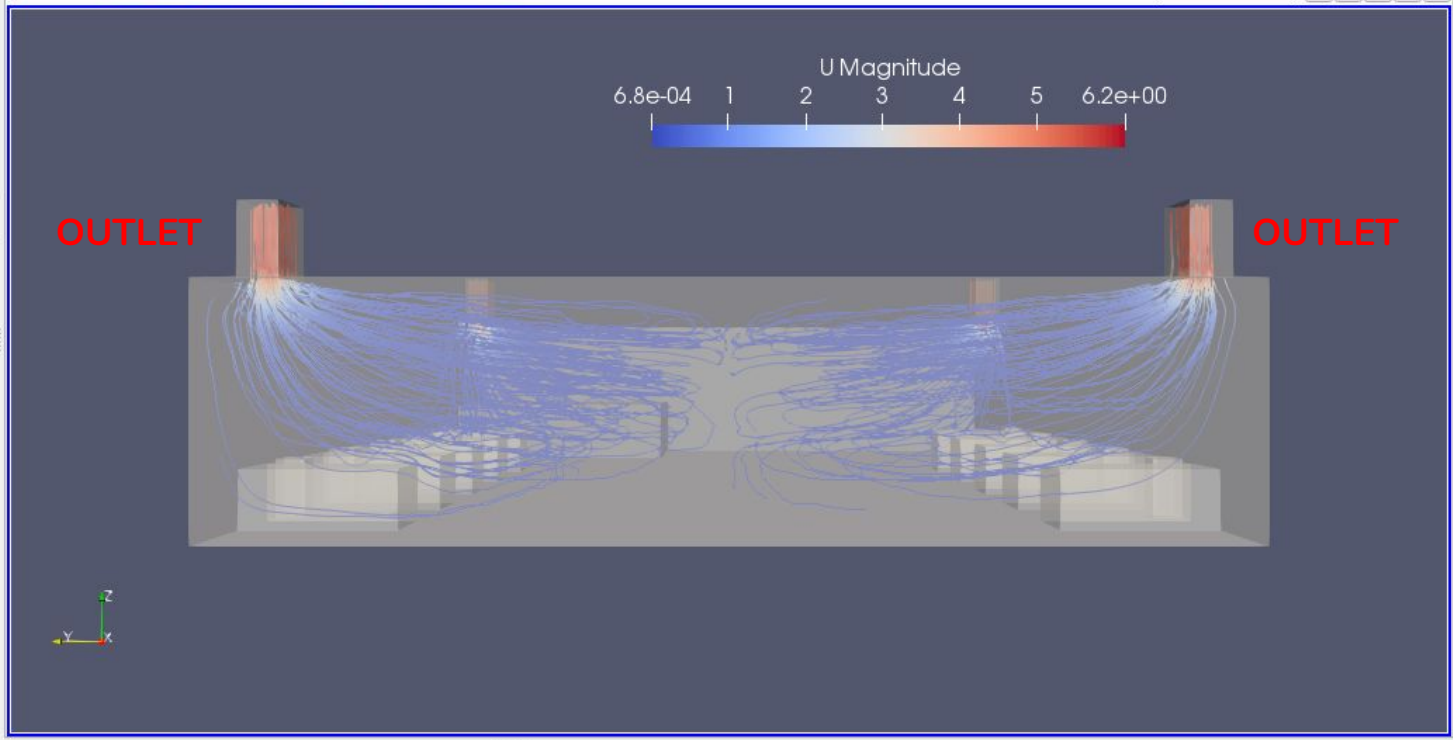

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Camera Parallel Projection

Layout #1 +

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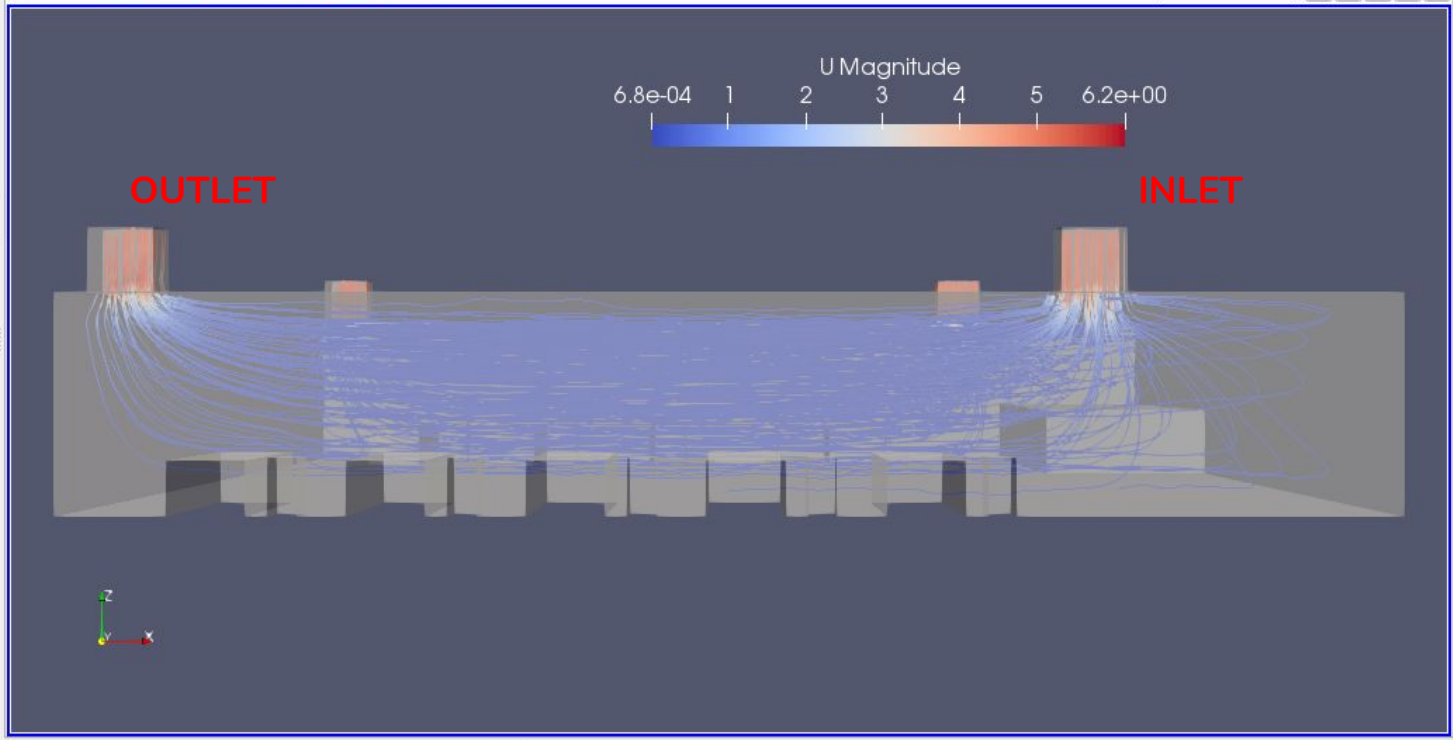

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Layout #1 +

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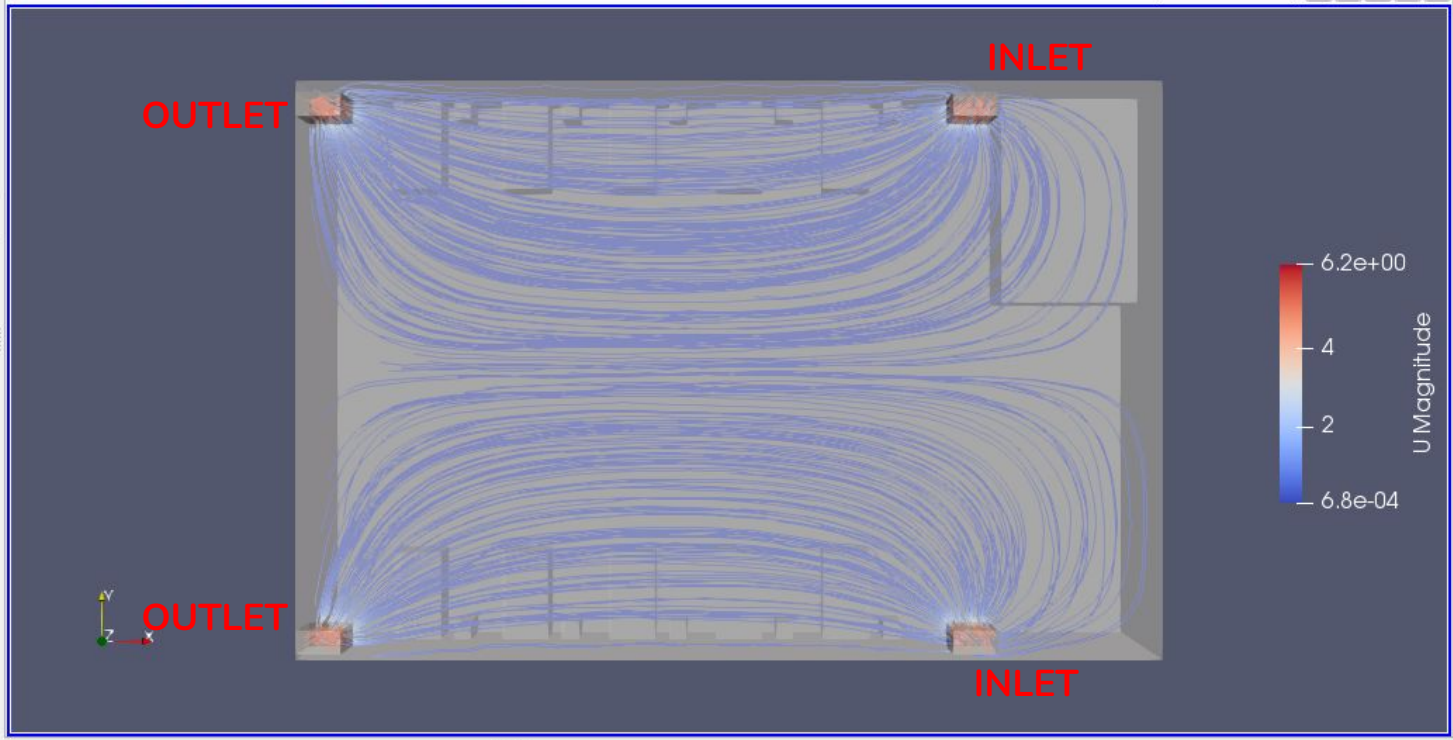


3.3 2_branch_pair_shifted

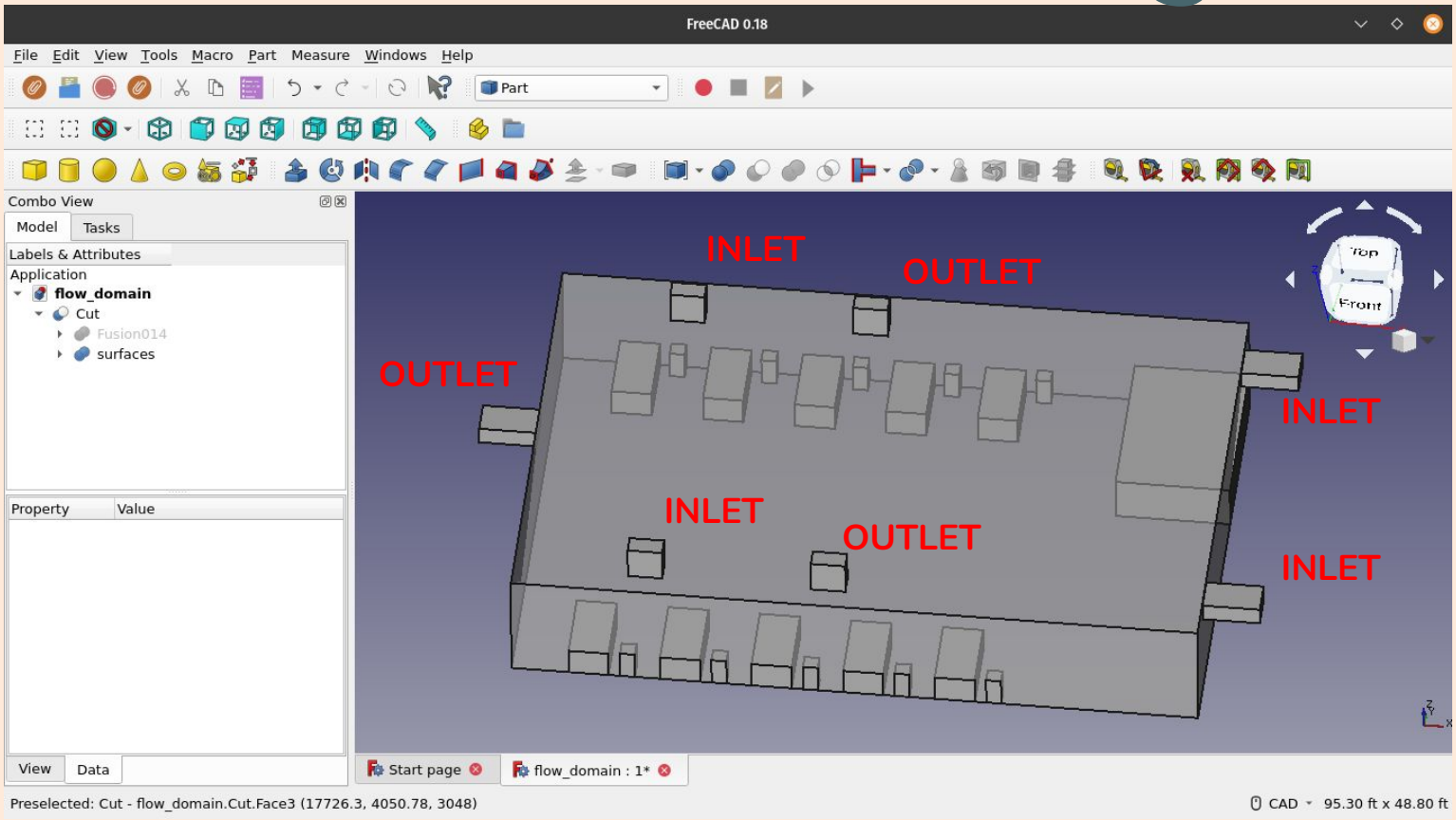
Key Takeaways:

- Shifting the beds improves air circulation near them.
- There are still regions where flow is negligible.

Next steps:

- Use both ceiling and wall-mounted vents
- Try adding more inlets to improve circulation at nurse station.

3.4 3_wall_4_ceiling



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Lagrangian Arrays

Layout #1 +

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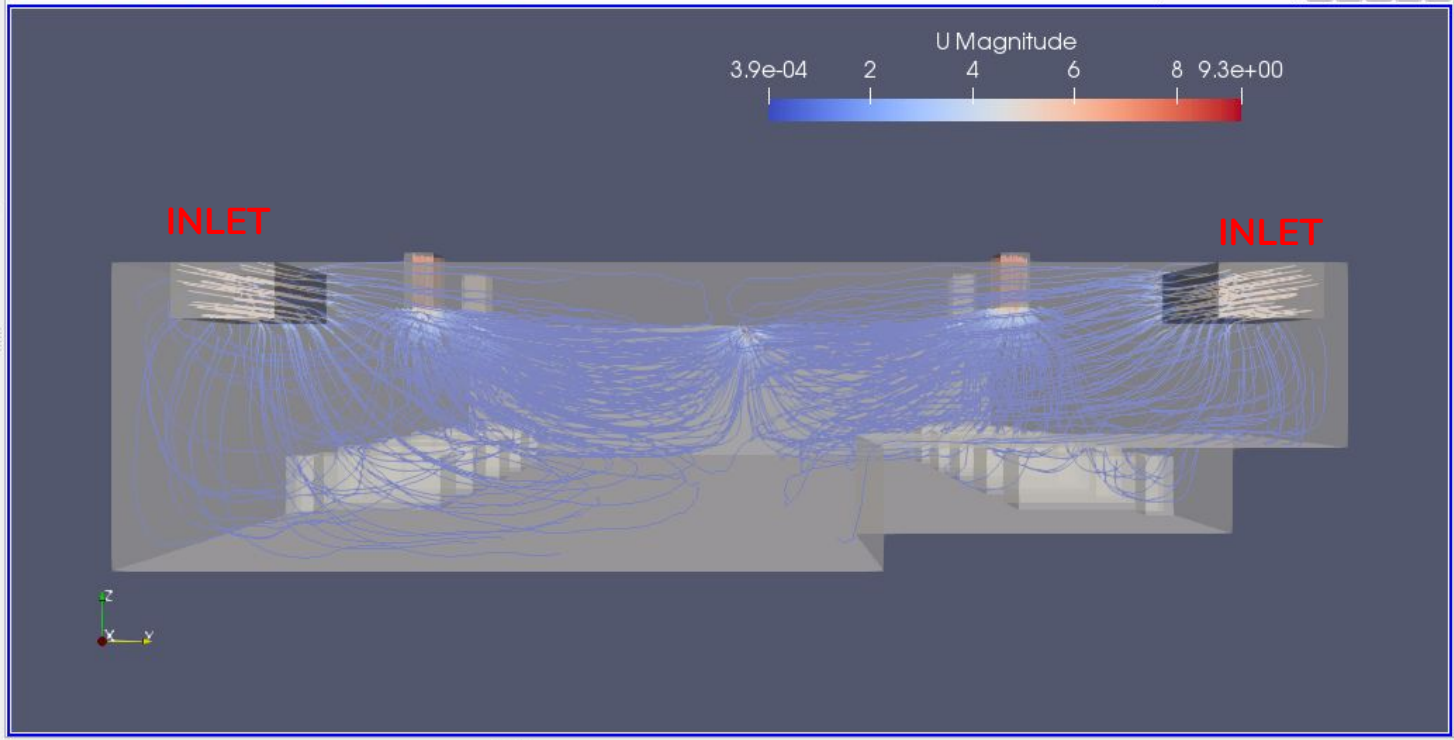

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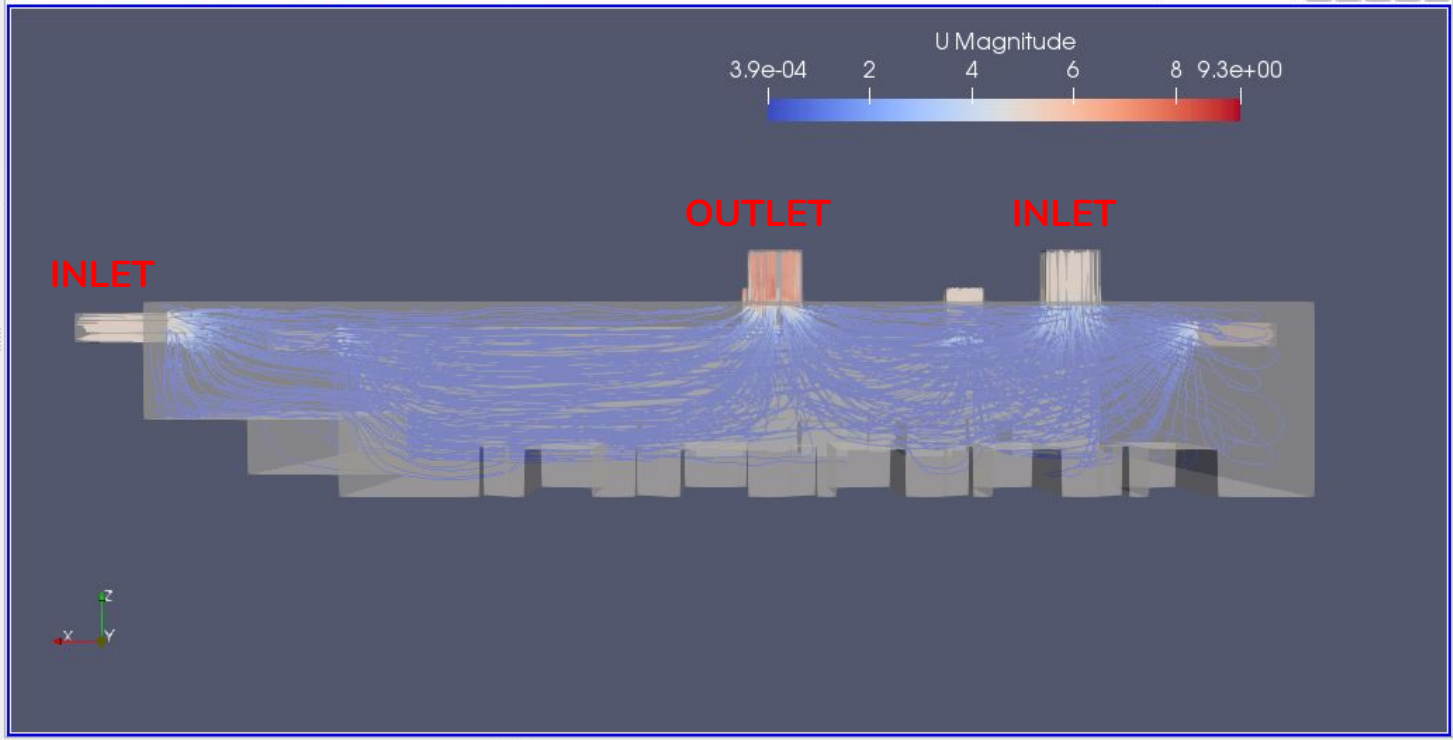

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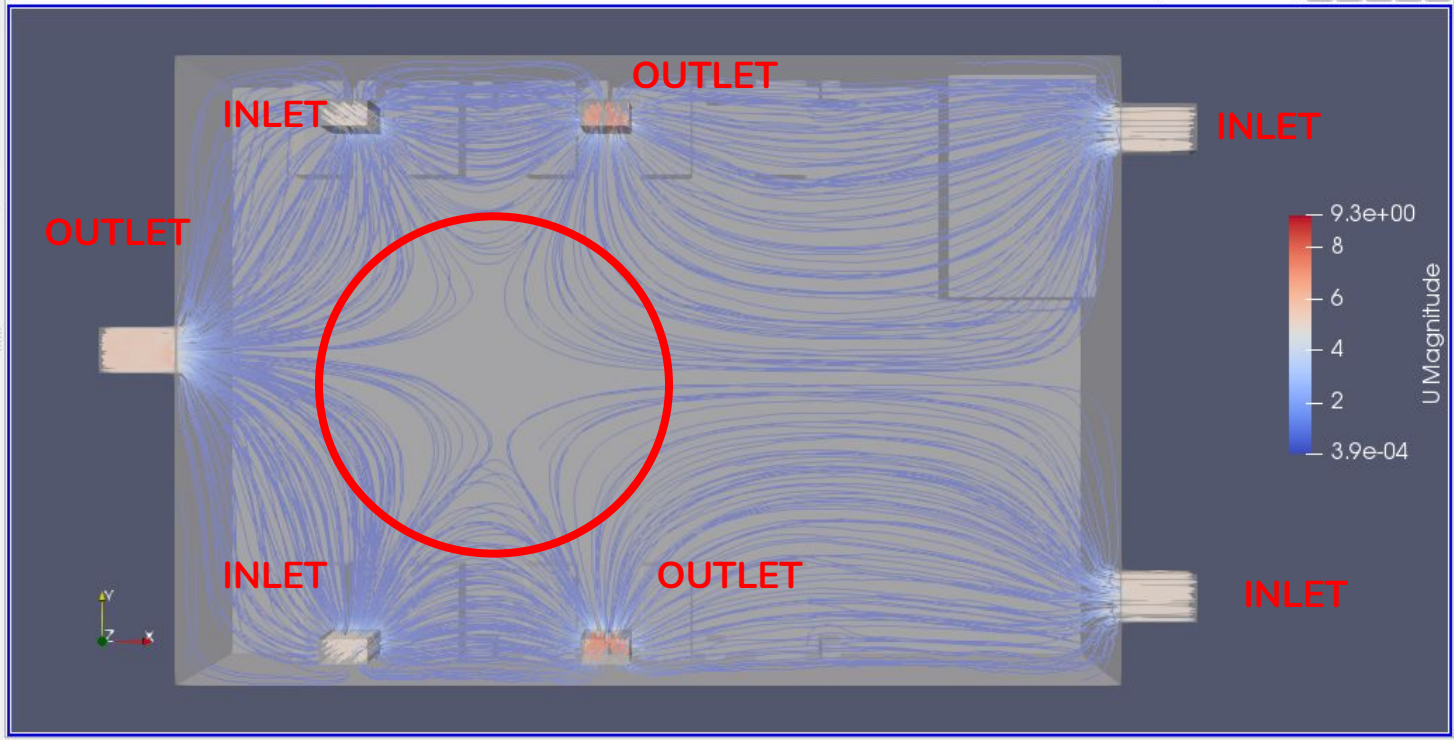
Layout #1 +

RenderView1



3.4 3_wall_4_ceiling

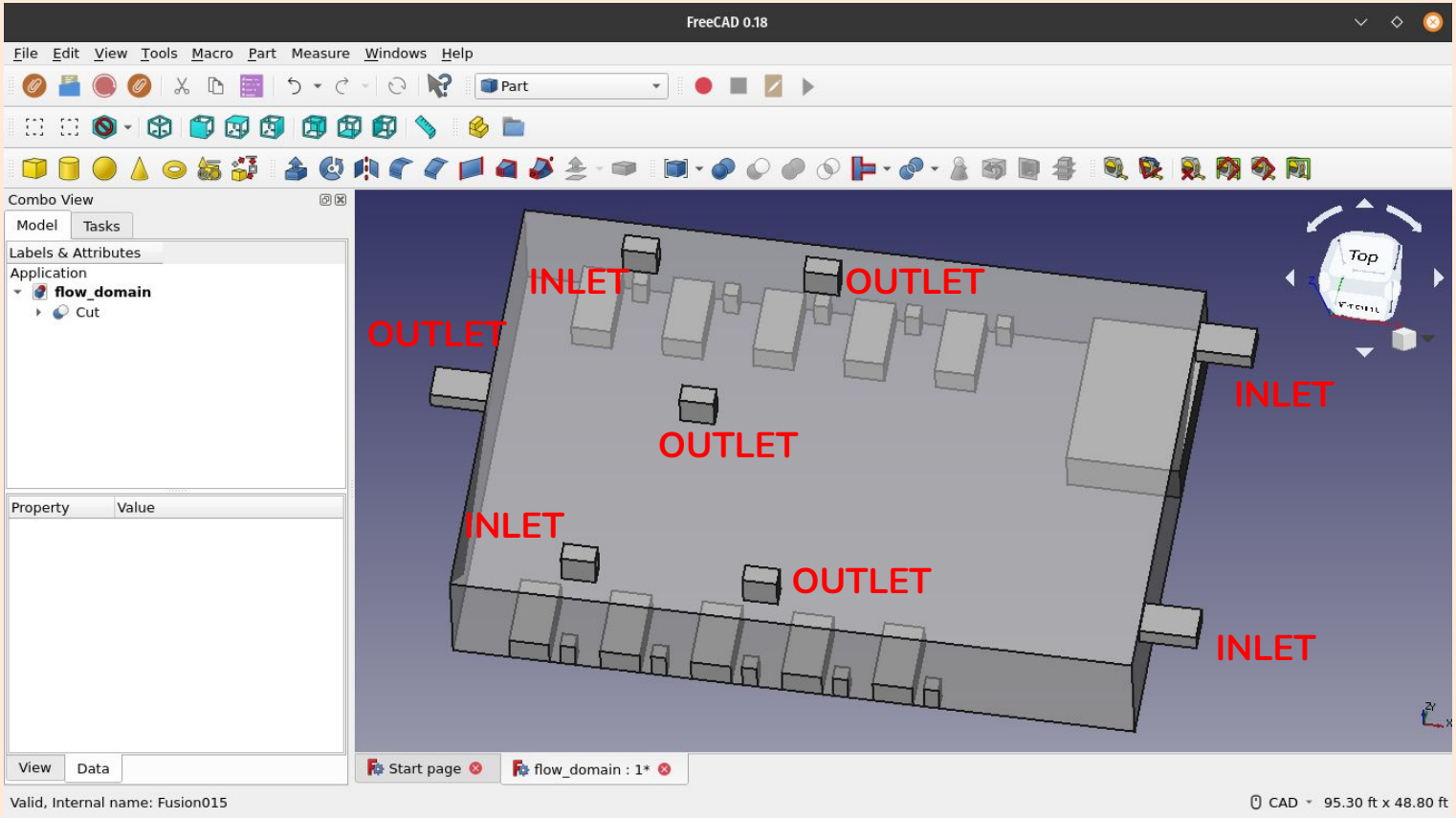
Key Takeaways:

- The nurse station receives good airflow.
- There is a large volume in the middle of the room, which needs proper ventilation.

Next step:

- Try adding ceiling-mounted outlet in the middle.

3.5 3_wall_5_ceiling



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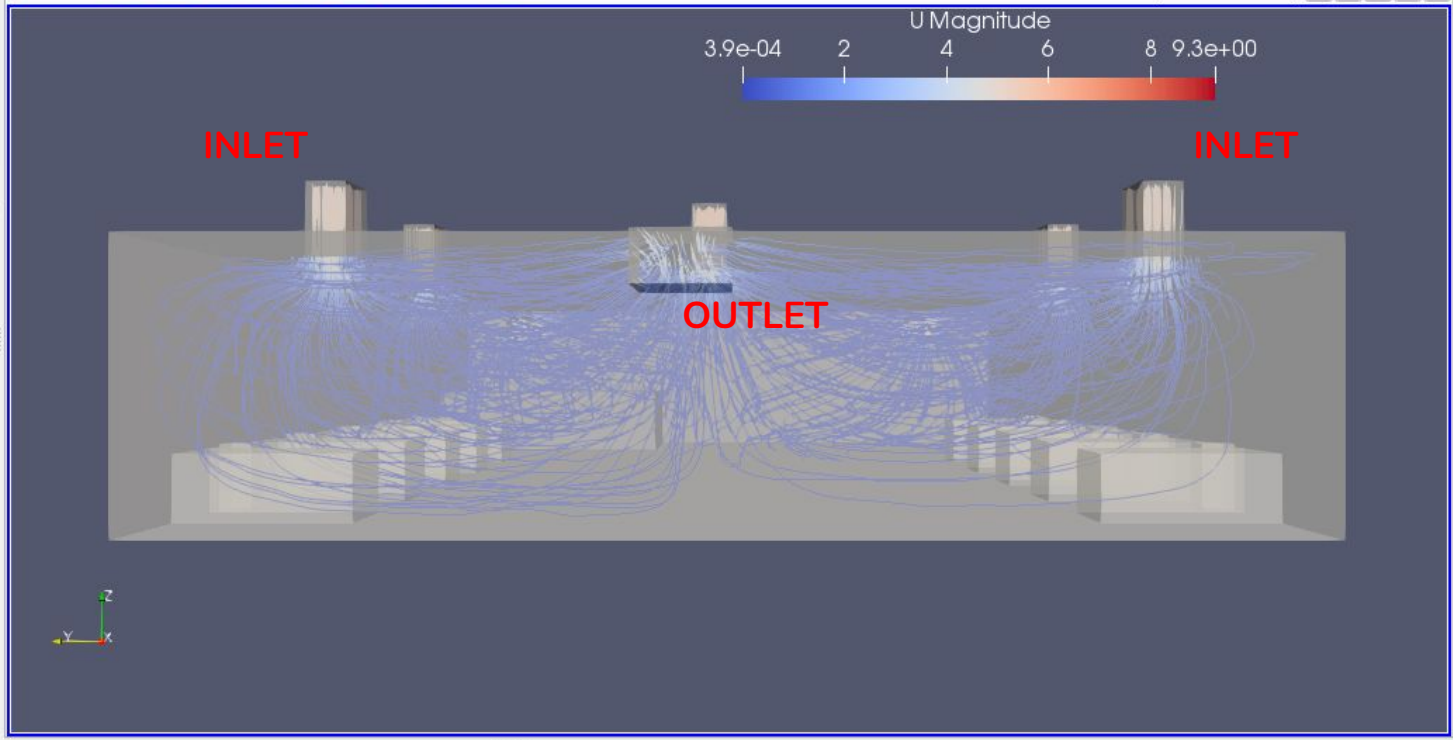

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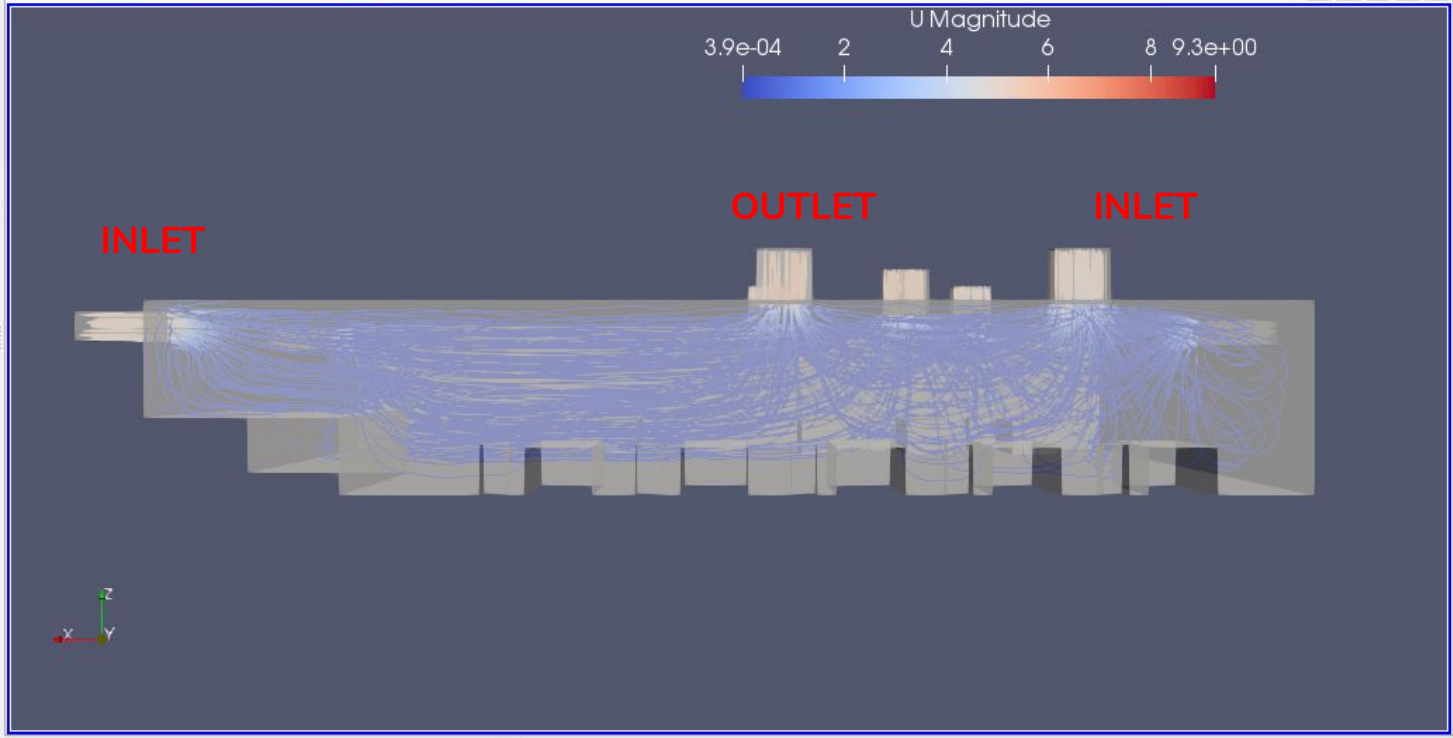

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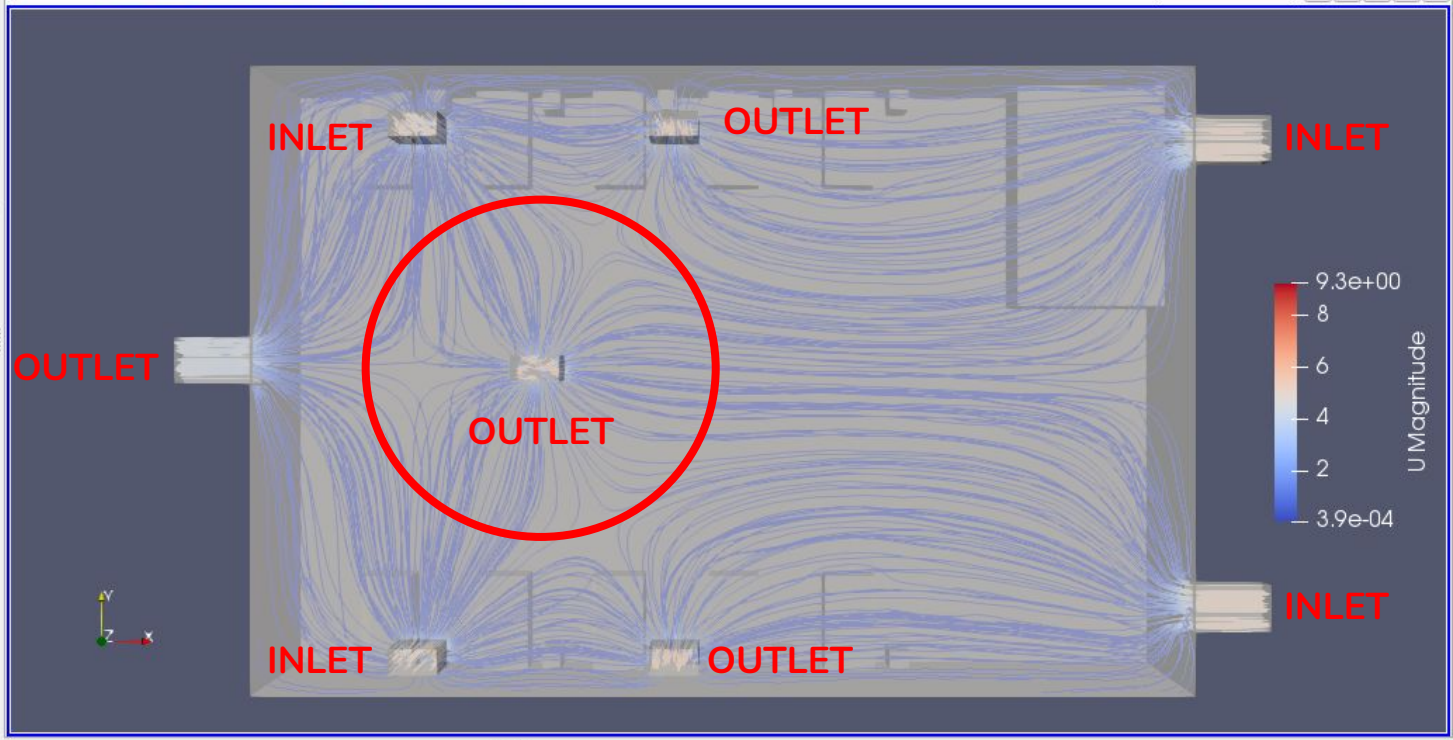
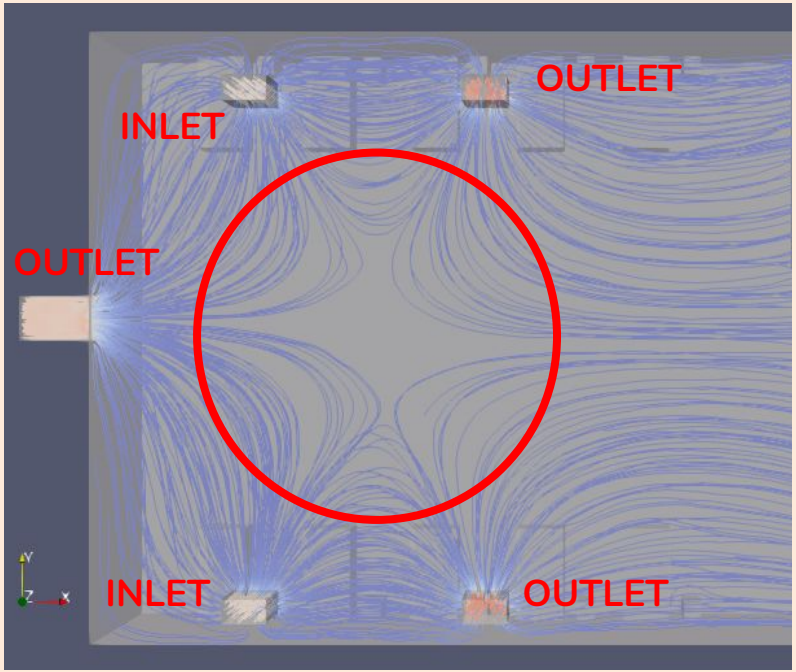
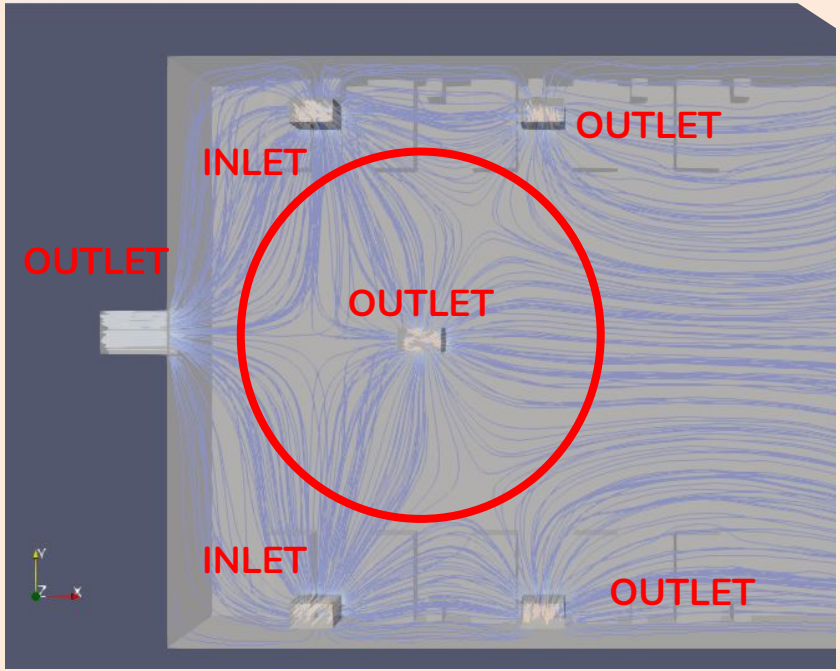


Comparison



3_wall_4_ceiling



3_wall_5_ceiling

3.5 3_wall_5_ceiling

Key Takeaways:

- Adding the ceiling mounted outlet in the middle significantly improves the airflow.
- The number of inlets and outlets is perfectly balanced.

Next steps:

- Try replacing a wall mounted inlet with a ceiling mounted inlet, to see effect on airflow.

4. Other Simulations

4. Other Simulations

S. No.	Case Name	Link
1	3_branch_one_main_pair	Link
2	2_branch_pair_no_main	Link
3	3_branch_1_main_shifted_bed	Link
4	3_branch_shifted_bed_shifted_main_one_out	Link
5	3_branch_shifted_bed_shifted_main	Link
6	2_wall_6_ceiling	Link
7	3_branch_pair_shifted	Link
8	3_branch_pair_1_outlet_shifted	Link

5. Next Steps

- Attempt to model turbulent airflow.
- Discuss our findings with microbiologists or hospital officials, and get their inputs.
- Share our code online in the open source domain (Link).

QUESTIONS?

6. References

S. No	TOPIC	DESCRIPTION
1	EPA recommendations for air purification	Discussion about HEPA filters and CADR ratings
2	Using UV to kill Covid 19 airborne particles in the UK	A preliminary scientific report examining using UV rays to purify air
3	STL vs STEP article	An article which explains the benefits of using STEP over STL
4	Parallel Computing with OpenFOAM	A tutorial explaining case setup for parallel processing using OpenFOAM
5	ParaView plot streamlines	A video tutorial walking through the procedure for plotting streamlines in ParaView
6	OpenFOAM course material	A collection of lecture notes explaining how OpenFOAM works and how to set up cases.
7	How to write Allrun and Allclean scripts	YouTube tutorials explaining how to automate running and cleaning cases
8	Piso Algorithm Explanation	A mathematical explanation of how the PISO algorithm is used to solve fluid flow problems
9	K-Epsilon model explanation	A YouTube tutorial explaining the K-e model for turbulence

THANK YOU!