INVESTIGATION OF THE VENTILATION SYSTEM OF THE COLUMBUS CREW ALTERNATIVE SLEEPING AREA

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AIM & OBJECTIVES

This project aimed to develop a comprehensive numerical model of the CASA air ventilation system, enhancing its performance, optimization, and overall efficiency without relying on traditional trial-and-error methods. To achieve the research goal of this project, the following objectives were set:

1. A critical analysis of the literature review on the ventilation system of the CASA will be conducted.
2. The current performance and efficiency indicators of the ventilation system of the CASA will be identified, and any gaps in the 'state-of-the-art' will be determined.
3. Experts in the field will be interviewed and surveyed.
4. A numerical CFD model of the current ventilation system of the CASA will be developed.
5. The efficiency of the CASA ventilation system will be investigated using the
6. CFD-validated model and alternative enhanced designs will be proposed.

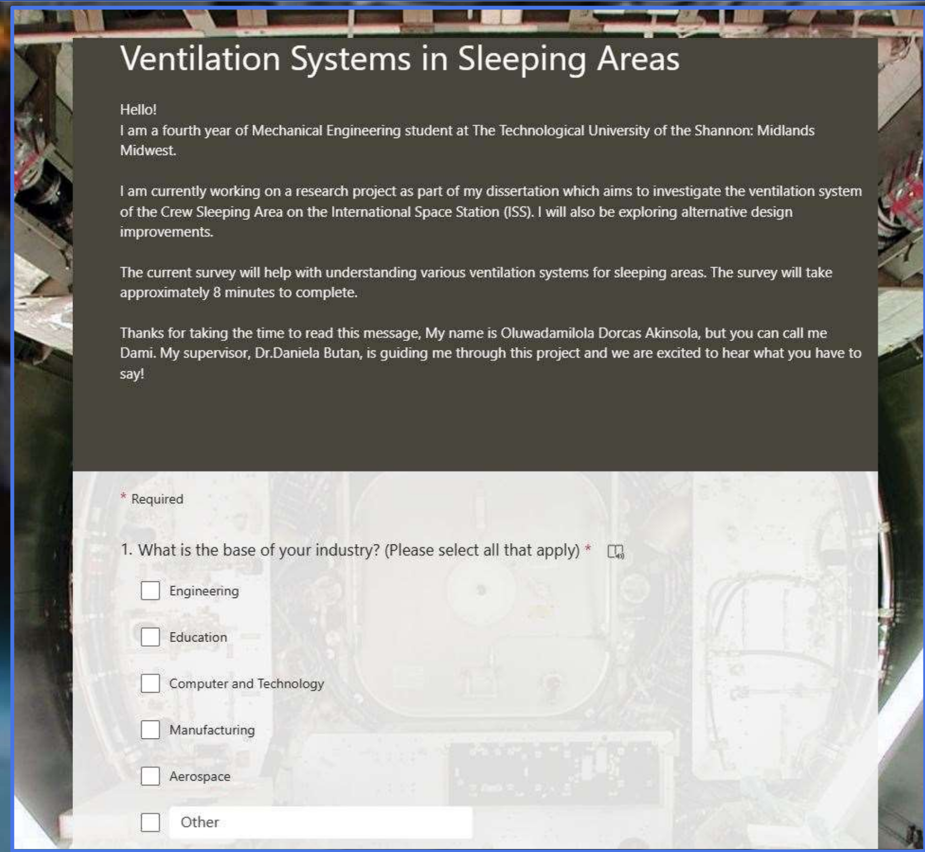
BACKGROUND- CASA

Crew quarters (CQs) on the International Space Station (ISS) provide privacy comparable to home environments, allowing astronauts to sleep without interruption. The Crew Alternative Sleeping Area (CASA) is a recent addition located in Columbus Laboratory, enhancing the comfort of the crew and providing a serene environment for relaxation.

CASA Interior

SURVEYS AND INTERVIEW

To gather data, surveys were carried out and an interview was conducted with Dr. Norah Patten from a Bioastronautics Researcher at the International Institute of Astronautical Sciences (IIAS) and Bailey Burns an experienced Systems Engineer at BLUE ORIGIN working on the ECLSS system.



Ventilation Systems in Sleeping Areas

Hello!
I am a fourth year of Mechanical Engineering student at The Technological University of the Shannon: Midlands Midwest.

I am currently working on a research project as part of my dissertation which aims to investigate the ventilation system of the Crew Sleeping Area on the International Space Station (ISS). I will also be exploring alternative design improvements.

The current survey will help with understanding various ventilation systems for sleeping areas. The survey will take approximately 8 minutes to complete.

Thanks for taking the time to read this message, My name is Oluwadamilola Dorcas Akinsola, but you can call me Dami. My supervisor, Dr.Daniela Butan, is guiding me through this project and we are excited to hear what you have to say!

* Required

1. What is the base of your industry? (Please select all that apply) *

- Engineering
- Education
- Computer and Technology
- Manufacturing
- Aerospace
- Other

Survey

Norah (Guest)	And just on the oxygen level, during Apollo 1 way back when they were starting human space travel to the moon, they had 100% oxygen in the CQ, and it caught on fire and the three astronauts died. So, it's a good case study to add in terms of things that we've learnt, during exploration and people have died because of certain things that have gone wrong. I mean I think that's a very good case study to add in. When you're talking about that.
Bailey (Guest)	Go look up Applo-1 for sure. There are a lot of lessons learnt there. And spacesuits even now. They use, I think, 100% oxygen. So, like, the suit itself is 100% oxygen. The living environment is not, because of that risk. We don't want that risk with the suits. They think they can control it enough to wear it's okay, but as Norah said, it's still a high risk for fire, which is like, probably one of the biggest things that we talk about in designing around fire. Yeah.
Dami (Interviewer)	So even though the suits are 100% oxygen does that mean that most of the materials used for the suits are anti-flammable or is it just some of them and then the parts that aren't interacting with the oxygen are flammable material?

Interview

IIAS Logo

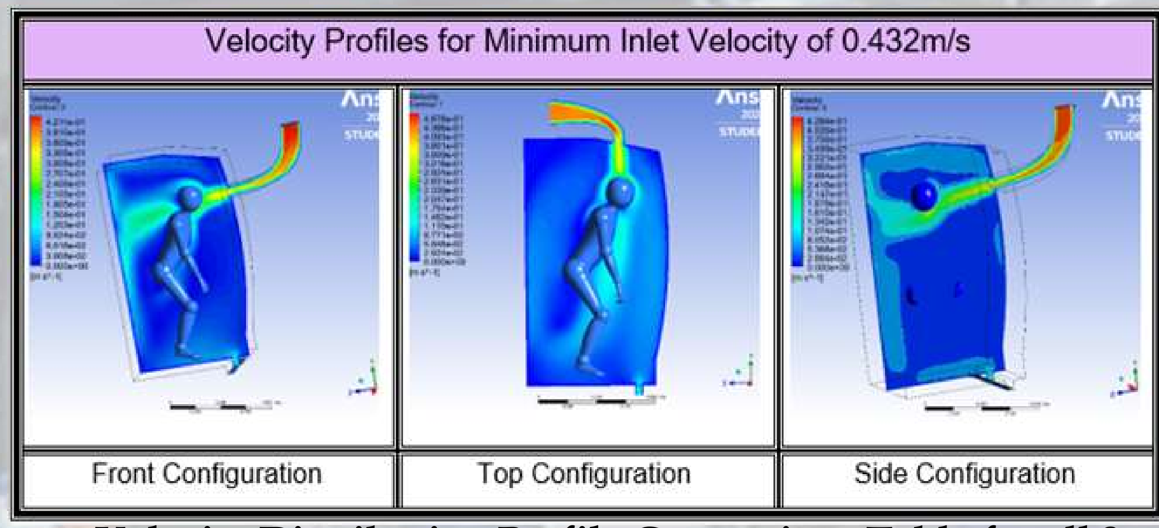
Blue Origin Logo

CFD SIMULATION

A simulation was conducted using ANSYS Workbench to analyse fluid flow in three cases with varying inlet velocities. The geometry was generated in Design Modeler, and a Boolean operation was created to prevent fluid from passing through the mannequin. The mesh was created, and boundary conditions were set. The viscous SST k-omega model was used to represent turbulent flow behaviour in the CQs.

The initialization method was selected, and the simulation was run with 100 iterations to reach convergence. Results were obtained and the process was repeated for the Top and Side configuration.

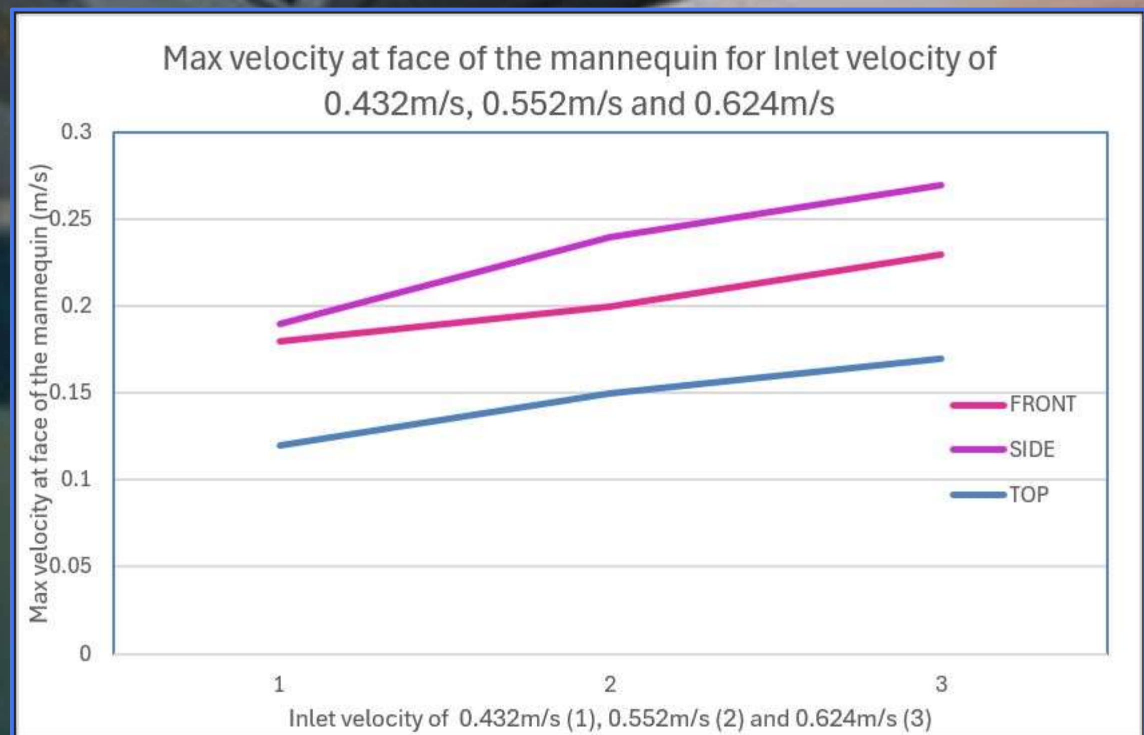
RESULTS



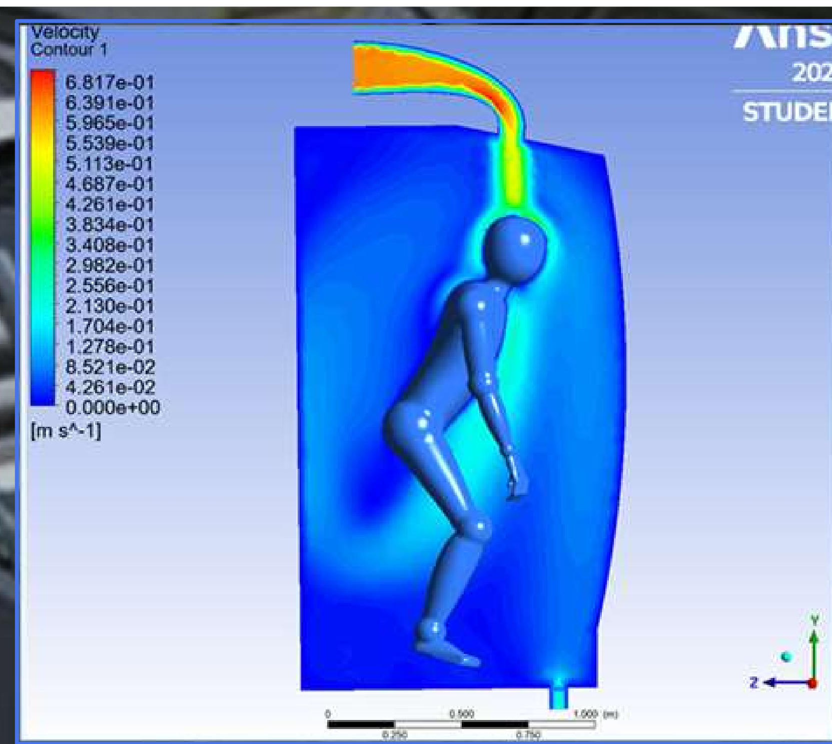
Velocity Distribution Profile Comparison Table for all 3 Configuration for Inlet Velocity of 0.432m/s

The study focuses on maximum velocity at the face of the mannequin in the CASA, following NASA Human Design Recommendations.

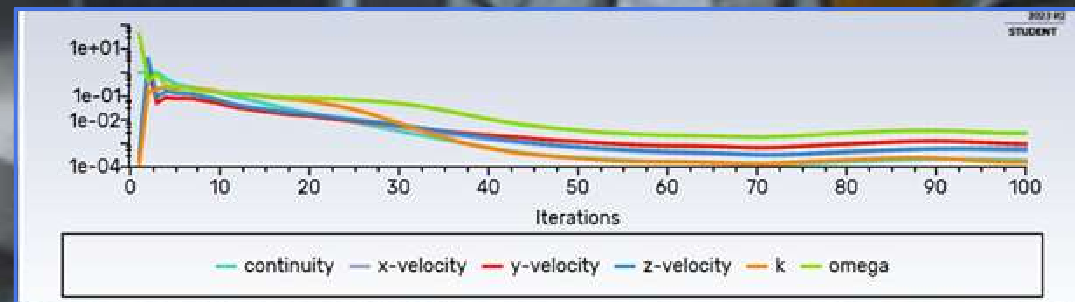
- Both the 'FRONT' and 'SIDE' configurations failed the recommendations, as the maximum velocities exceeded the upper limit of 0.2m/s.
- The 'TOP' configuration, with inlet air at the top of the CASA, has a max velocity below 0.2m/s.
- The 'TOP' configuration shows the most uniform velocity distribution inside the CASA and across the mannequin's body.
- The air velocity at the mannequin's face or the 'TOP' configuration was 0.12m/s, corresponding to values in Case Study 2 of the literature review whose face velocity (comfort zone velocity) was 22ft/min (0.1176 m/s), giving a percentage error of 9.09%, which is acceptable as CFD simulations allow a maximum percentage difference of 10%.



Comparison Line Chart for all Three Configurations



Velocity Distribution Profile for the TOP Configuration at Inlet velocity 0.432m/s.



SST k-model Residual Chart for the TOP Configuration at Inlet velocity 0.432m/s.

CONCLUSION

This study on ventilation systems in space has found that the 'TOP' configuration, with an inlet at the top of the cabin crew and a velocity of 0.432 m/s, is most effective in meeting NASA's ventilation flow requirements. This configuration maintains comfort levels below the recommended 0.2 m/s velocity.
However, further research and validation are needed to assess its overall efficiency and comfort coefficient comprehensively. Future studies could also explore additional parameters like temperature and pressure profiles to provide a more comprehensive understanding of ventilation performance within the CASA CQ. This study emphasizes the importance of optimizing ventilation design and operation to enhance occupant well-being and productivity, ensuring the success of human space missions.

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