



Adaptive Ventilation in Hospital : Visualization, User Interaction and Real-Time Control

AI+XR Real-Time Visualization for Life-Saving Infection Control in the OR

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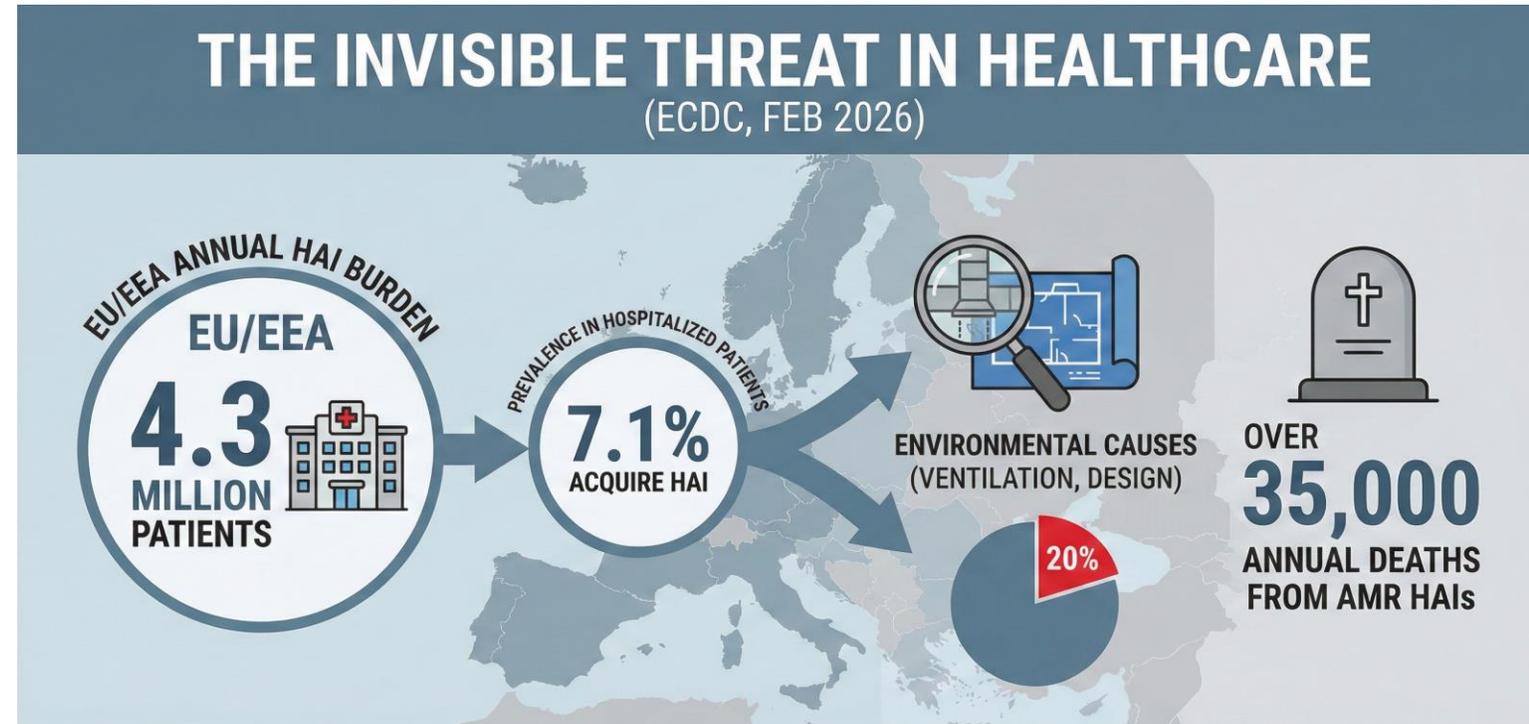
Light + Building Fair 2026 • REHVA Seminar • Frankfurt



Invisible, Unmonitored, Uncontrolled Threats



- 4.3 million healthcare-associated infections (HAI) annually in EU/EEA*
- 7.1% of hospitalized patients acquire at least one HAI*
- 20% of HAI caused by hospital environment and ventilation design*
- 35,000+ deaths annually from antimicrobial-resistant infections*



*Updated data from ECDC, WHO, EU

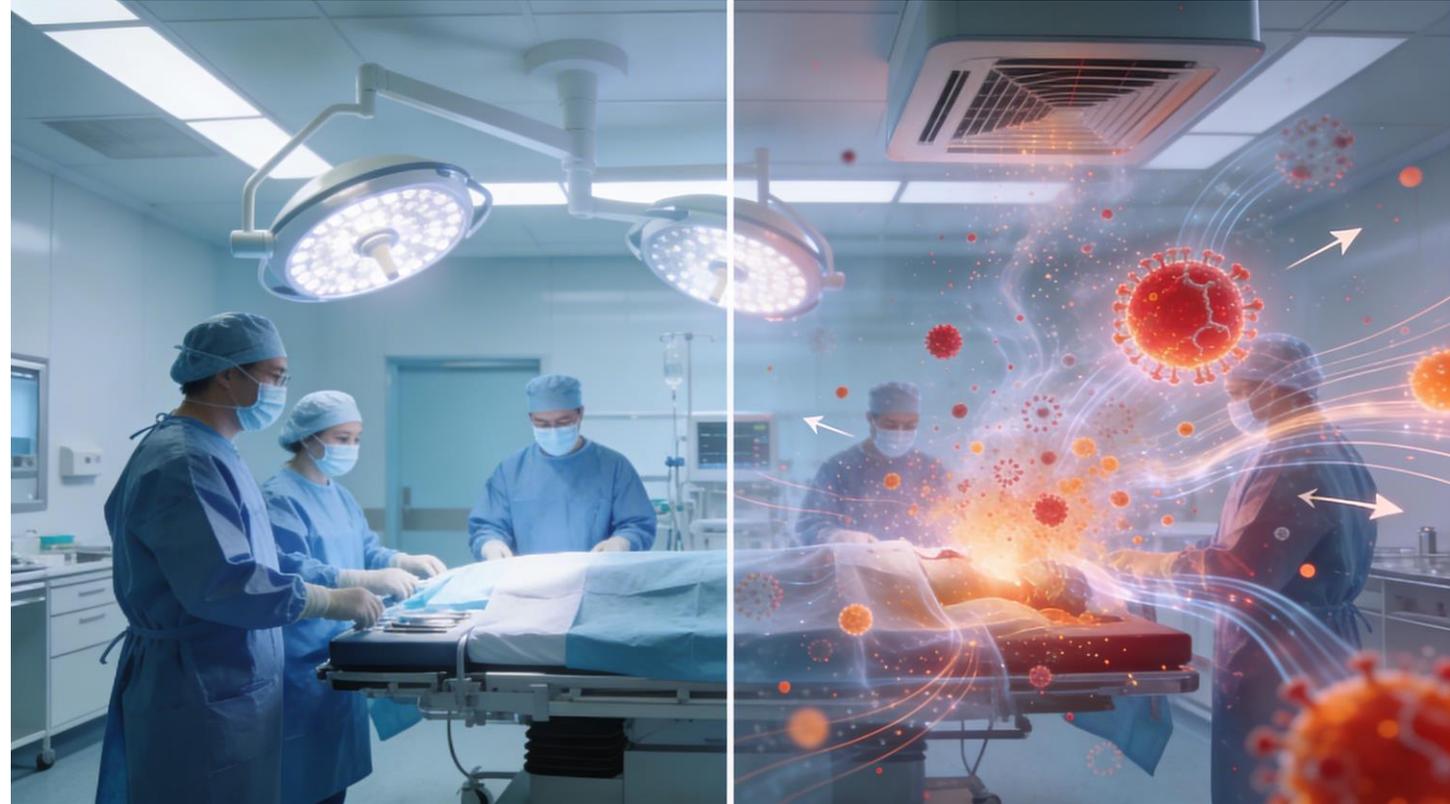


Current Ventilation Monitoring



Retrospective analysis :

- No real-time visibility of airborne contaminants
- Energy optimization without infection risk awareness
- Surgeons work in environments they cannot assess



A New Paradigm

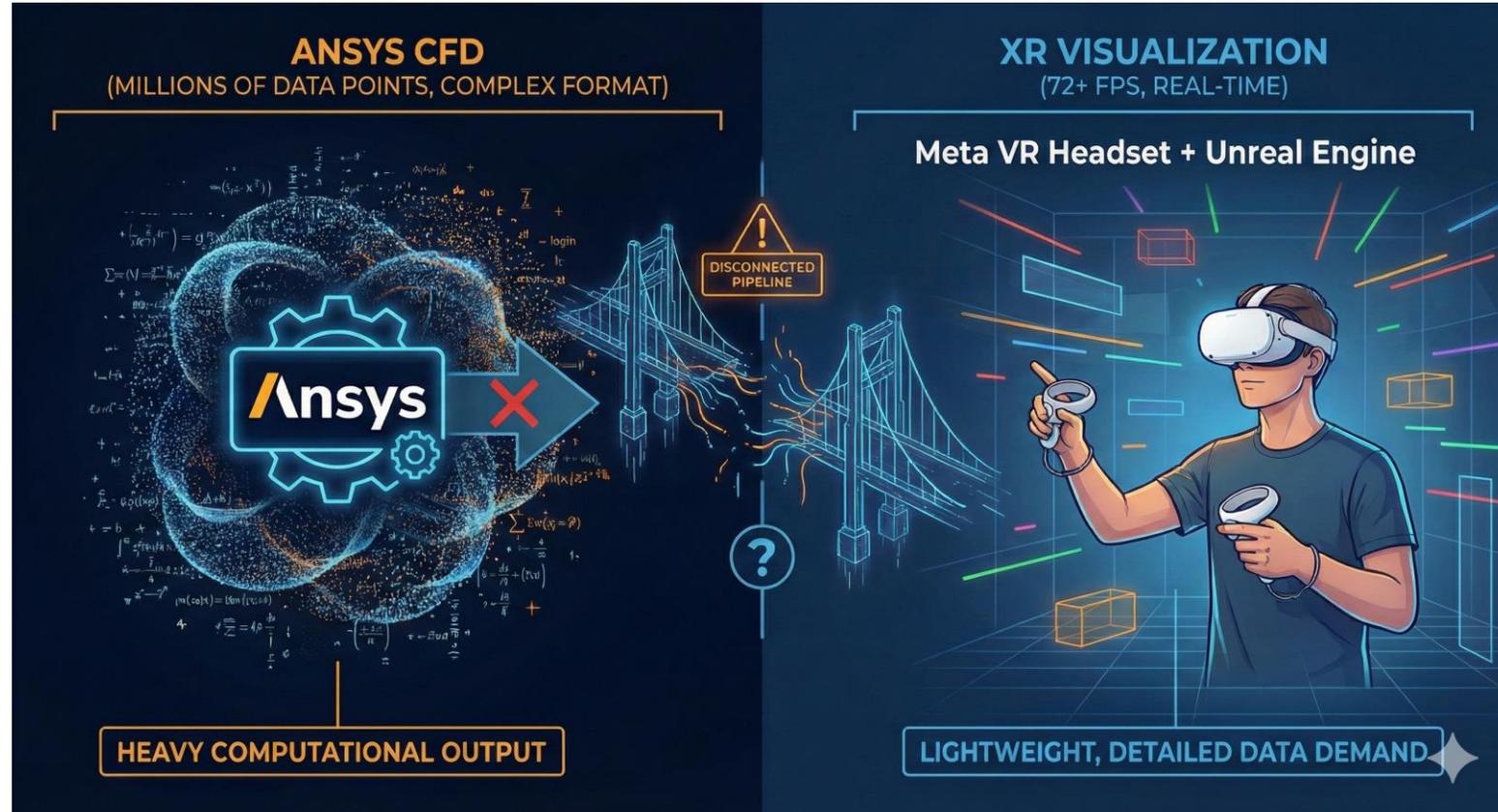


"As AI progresses exponentially, we cannot rely on conventional visualization methods for monitoring and infection control. Let AI help the surgeons by monitoring, analyzing OR conditions in real-time, and supporting decision-making to save more lives."



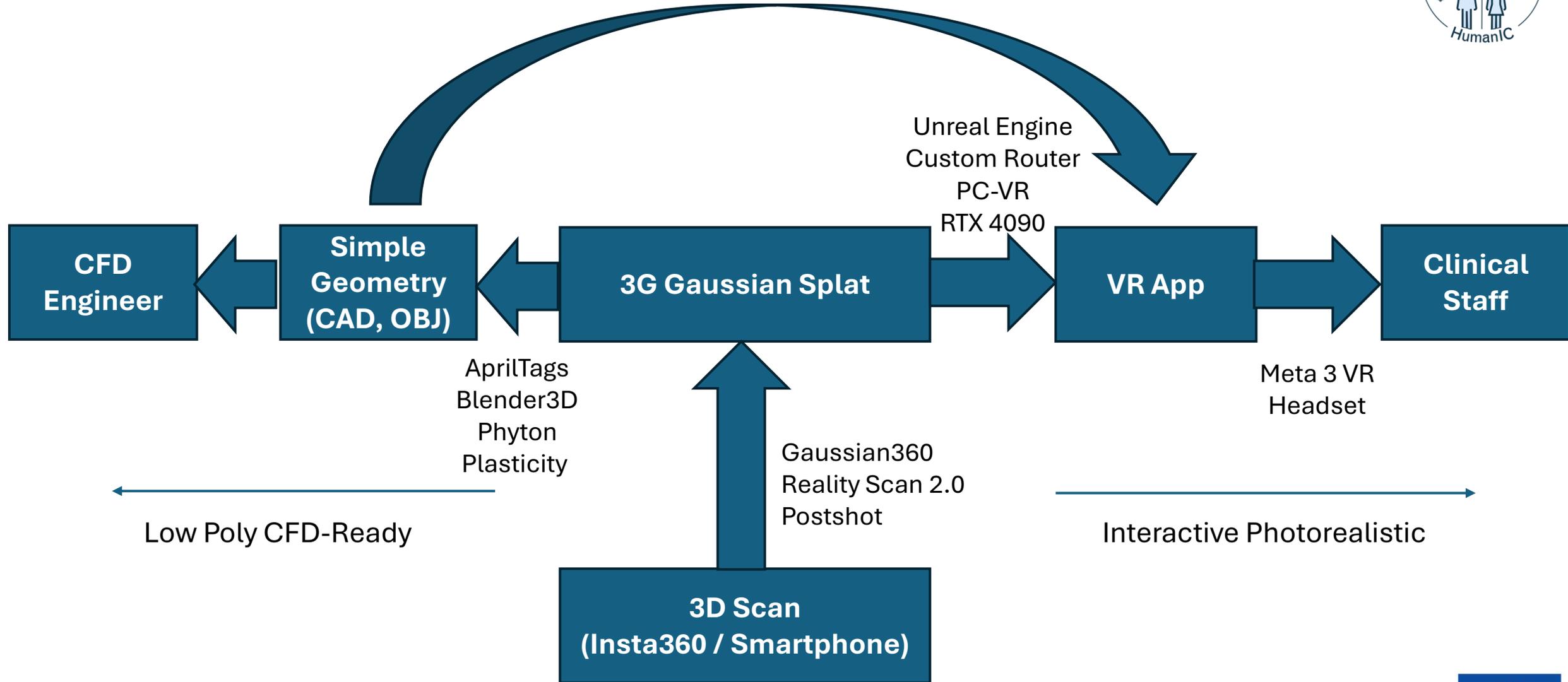
The Visualization Challenge

- CFD tools (Ansys) and XR engines (Unreal) don't speak the same language.
- CFD outputs: millions of data points, complex formats
- XR requires real-time rendering at 72+ FPS
- Gap: no seamless pipeline for immersive visualization





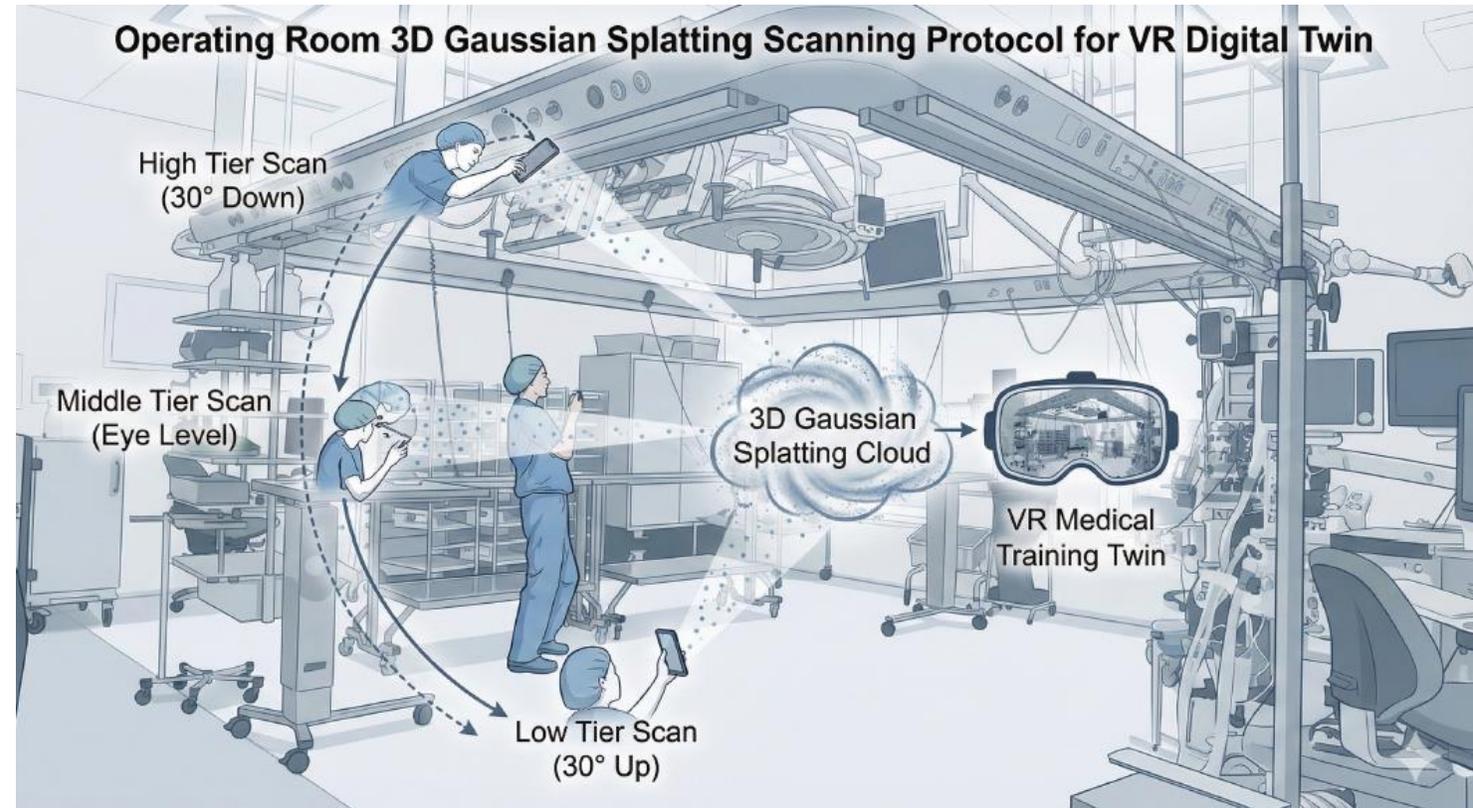
Scan to VR Workflow



3D Gaussian Splatting for Digital Twins

Do we need expensive DSLR cameras to scan operating rooms?

- Evaluated DSLR vs 360° vs Smartphone cameras
- Result: Smartphones win for perceptual quality (LPIPS)
- Optimized 3DGS: 72.6 FPS on RTX 4090





St. Olav's Hospital LAF OR

DLSR



Ground Truth



3DGS

St. Olav's Hospital MAV OR

DLSR



Ground Truth

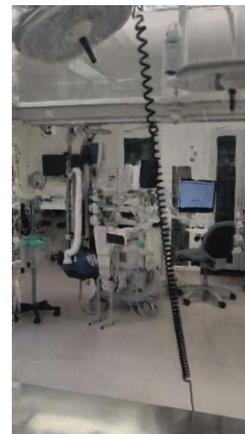


3DGS

Smartphone

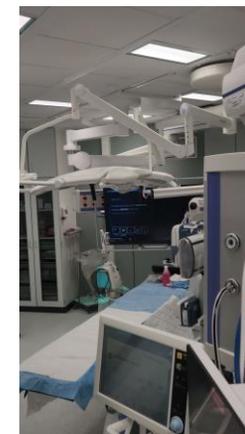


Ground Truth

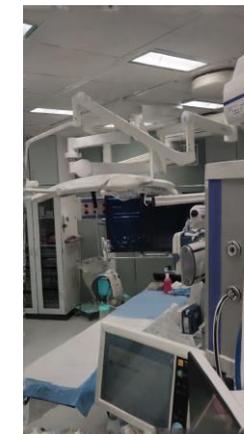


3DGS

Smartphone



Ground Truth



3DGS



NTNU HVAC LAB OR

iPhone 14 pro



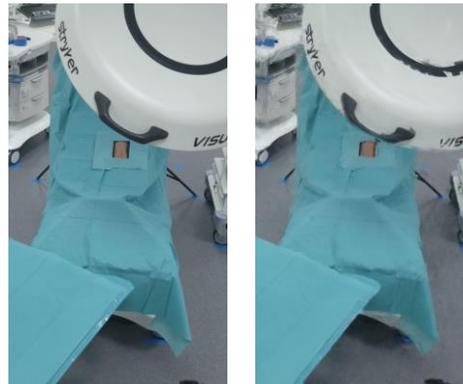
Ground Truth 3DGS

Samsung Fold 4



Ground Truth 3DGS

Samsung S21 Ultra



Ground Truth 3DGS

Insta360 X5



Ground Truth 3DGS

Photorealistic 3D Environment Creation



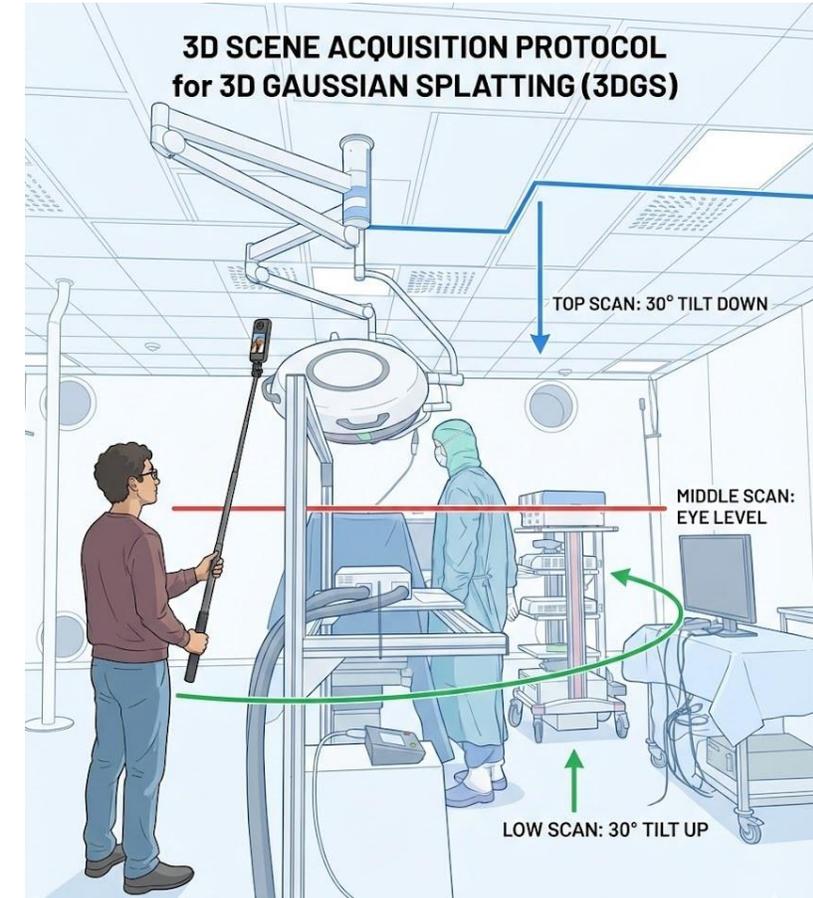
How We Capture and Reconstruct Real 3D Environments?

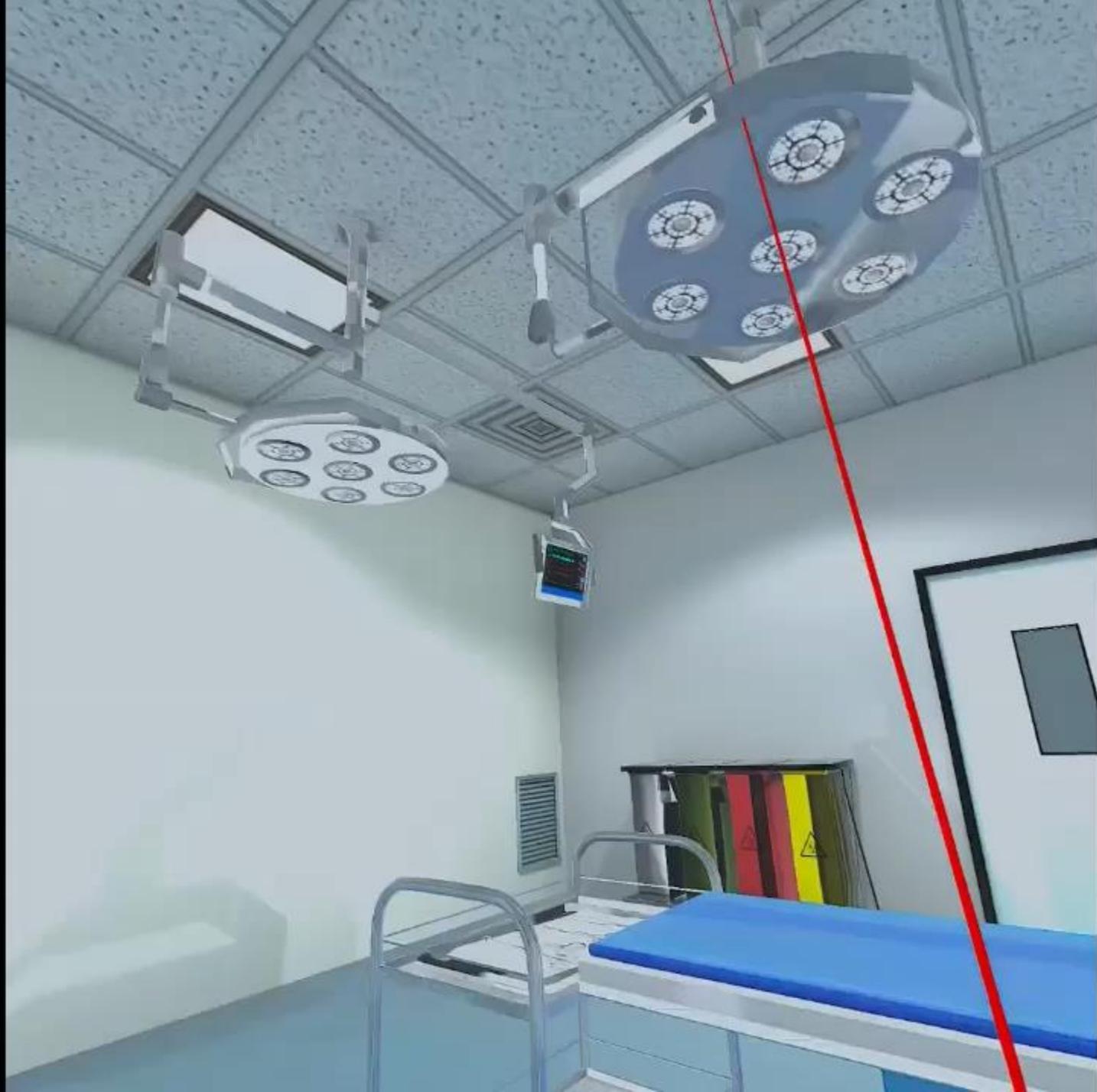
Step 1 : Capture -> Take multiple photos/videos of the operating room from different angles

Step 2 : Analyze -> Software identifies every point of light and color in the images

Step 3 : Reconstruct -> Convert points into millions of tiny 3D particles (Gaussians)

Step 4 : Render -> Combine particles to create photorealistic 3D environment in real-time

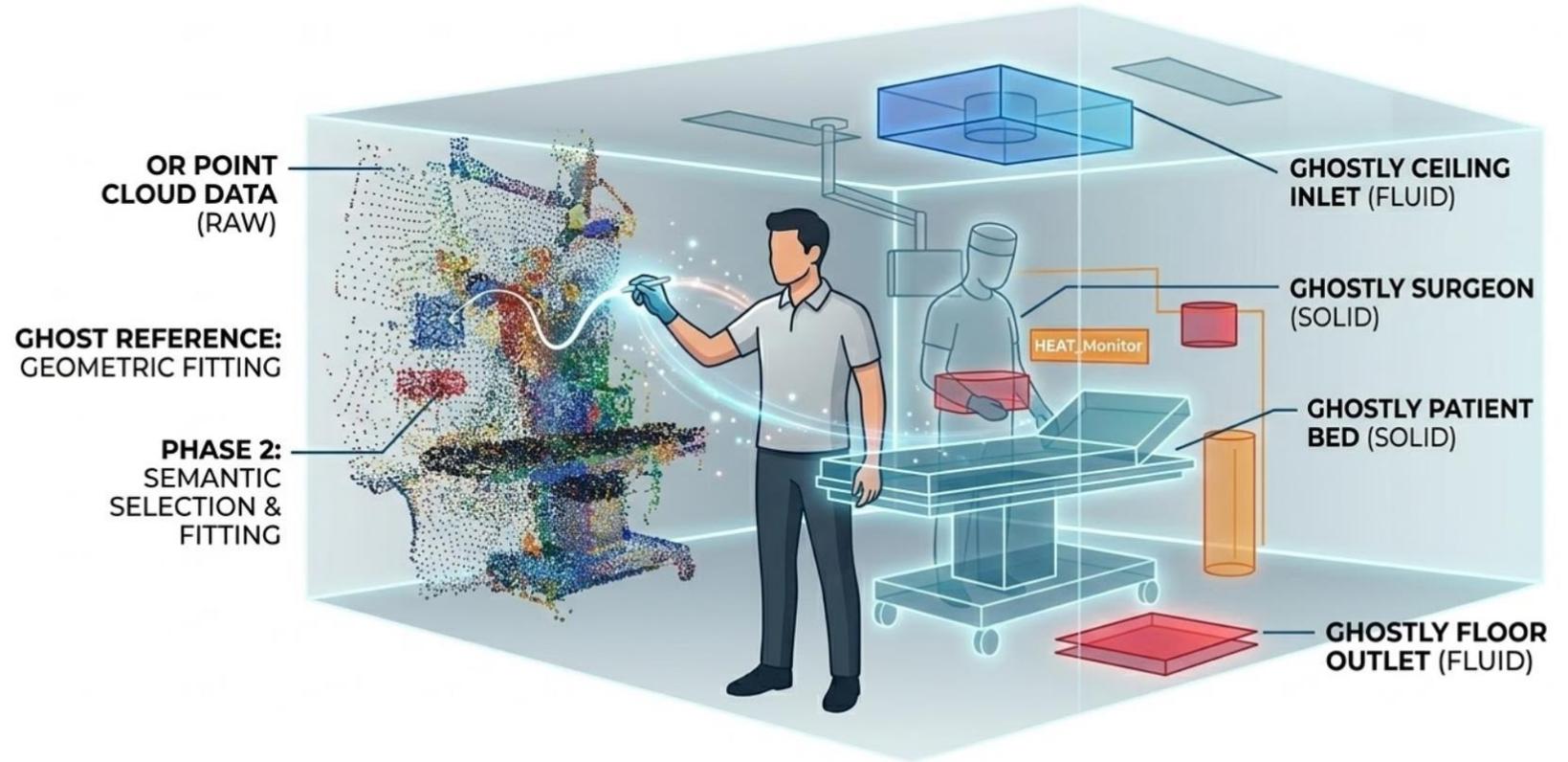




Digital Twin of Operating Room

- Treat the 3DGS point cloud purely as a visual, spatial scaffold.
- Empower the CFD engineer to act as an intelligent filter.
- Using AprilTags as positional and orientation anchor
- 1.65% error (10 – 11 mm) from the Ground Truth

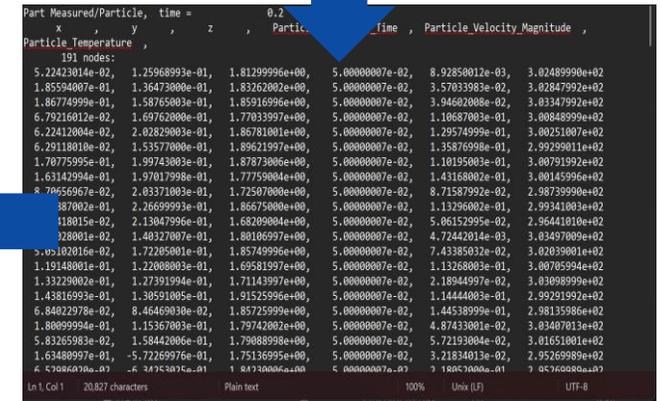
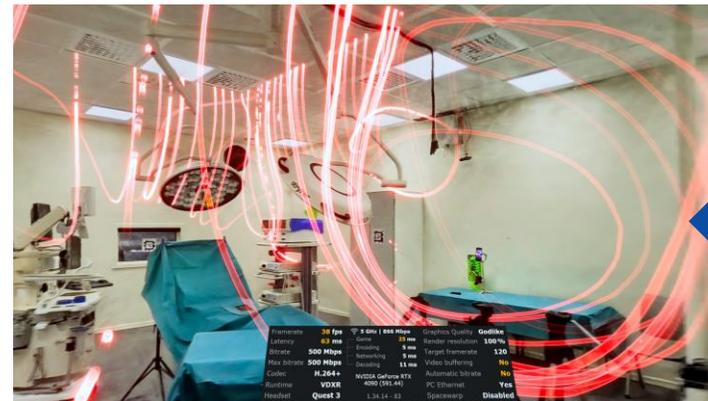
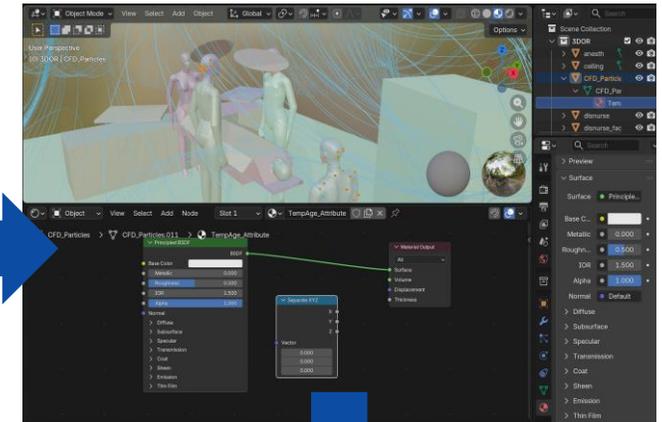
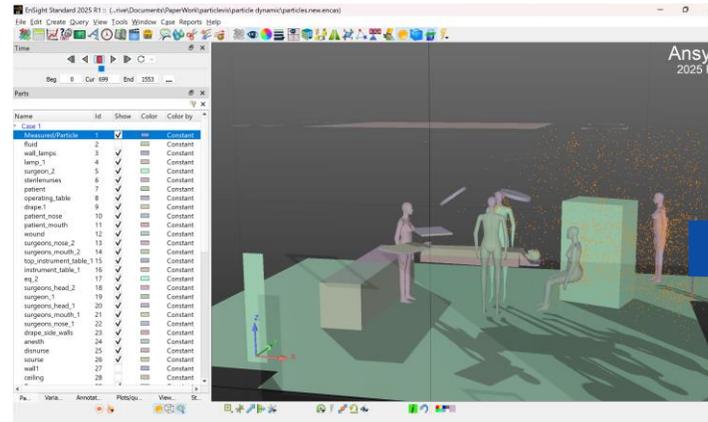
The Ghost Reference Workflow: Tracing Geometry Over Noise





Lagrangian-Based Middleware Solution

- Step 1: Extract particle tracking data from Ansys CFD
- Step 2: Python middleware processes in Blender 3D
- Step 3: Bake physics into mesh vertex attributes (position, velocity magnitude, age and temperature)
- Step 4: Import as animation into Unreal Engine



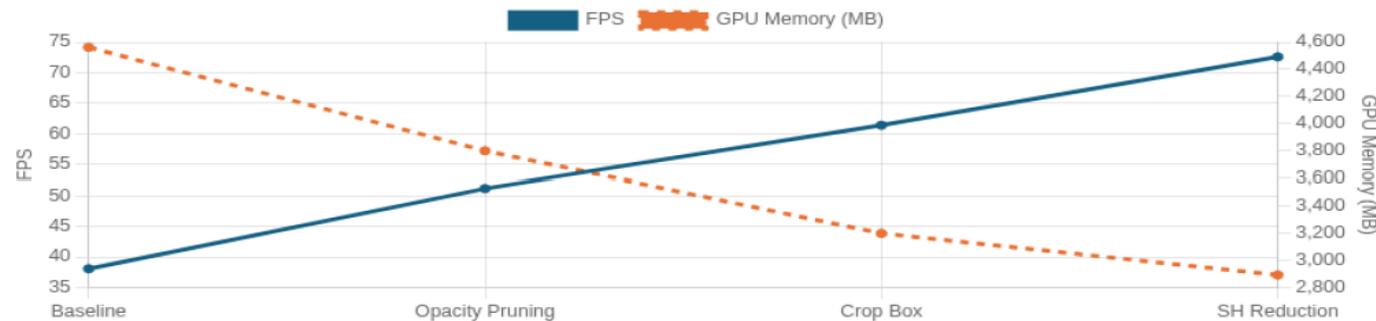


VR Performance of Indoor Climate Digital Twin

Camera System	PSNR	SSIM ↑	LPIPS ↓
Samsung S21 Ultra	22.90	0.92	0.28
iPhone 14 Pro	21.46	0.76	0.23
Z Fold4	17.14	0.84	0.35
Sony DSLR	20.77	0.75	0.34
Insta360 X5	34.14	0.98	0.05



3DGS Optimization Progression



91% FPS improvement, 37% memory reduction



Can Non-Expert Understand Airflow?



European Researcher's Night (Gdansk) Validation Study

- Gamified VR airflow simulation in Unity 3D
- Target: Children and families (non-experts)
- Result: Users intuitively grasped invisible risks



The Next Frontier: Real-Time AI

From calculating physics to predicting patterns.

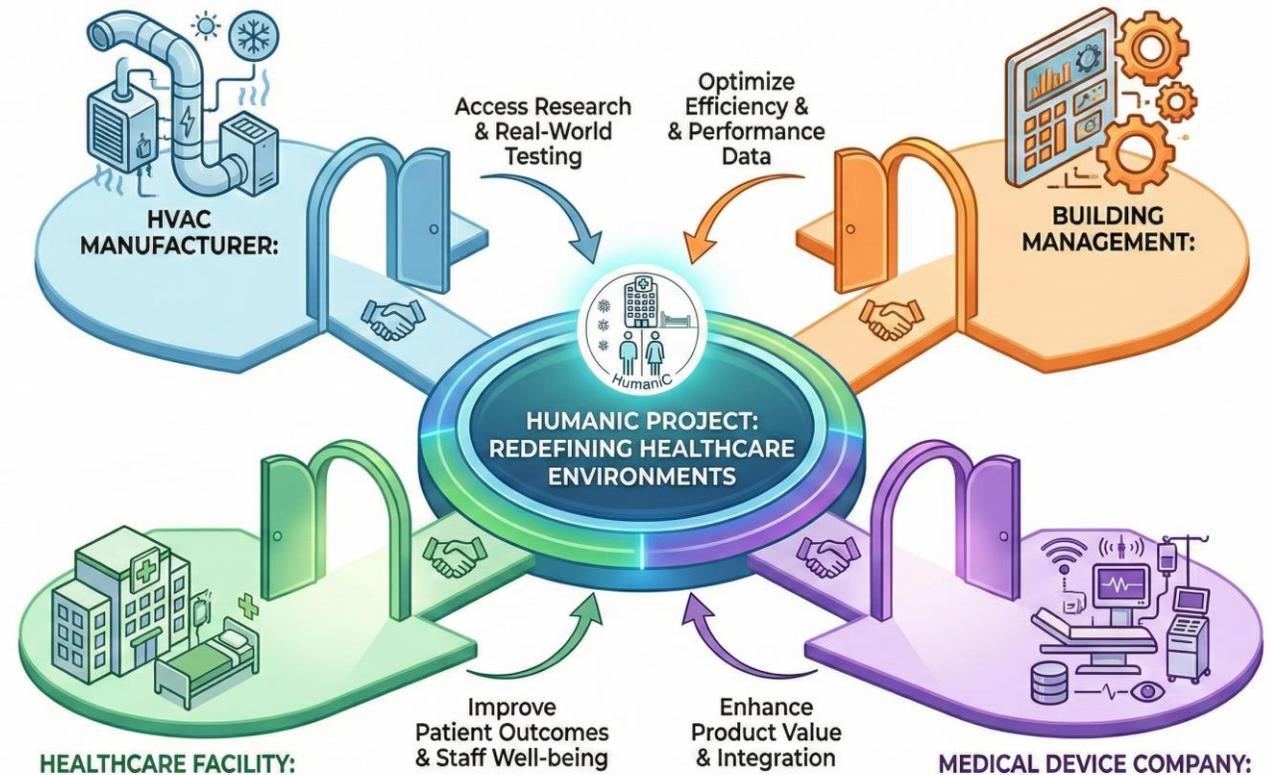
- Surrogate modeling: AI inference instead of solving
- Target: 10ms response time for adaptive control
- Goal: Surgeon interaction with instant airflow feedback



Collaboration Opportunities



- HVAC manufacturers: Integrate real-time monitoring
- Building management systems: AI-driven control APIs
- Healthcare facility designers: XR design validation
- Medical device companies: OR environmental awareness





Thank you

Let's make the invisible visible, together

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HumanIC Project: <https://human-ic.eu>

