AN IMMERSIVE, INTERACTIVE VIRTUAL WALKTHROUGH OF A MODERN AEROSPACE MAINTENANCE HANGAR

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Virtual Reality (VR), Aerospace Education, Immersive Learning, Jet Engine Simulation, Extended Reality (XR)

Introduction:

Extended Reality (XR)—encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—is transforming engineering education by enabling experiential, risk-free learning environments for complex systems. In aerospace engineering, where access to real jet engines is restricted due to cost, safety, and logistical constraints, XR offers a scalable alternative for teaching propulsion dynamics. Traditional methods relying on static diagrams or videos fail to convey the real-time interplay of internal engine components such as the main fan, high-pressure compressor (HPC), and turbines. This project addresses this gap by developing an immersive VR simulation of a half-cut turbofan engine, allowing students to control operations, inspect subsystems, and manipulate scaled 3D models—all within a standalone headset environment.

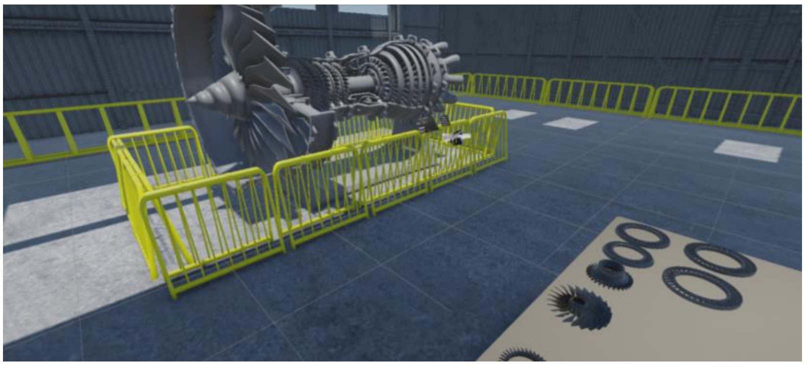

Figure 1: The half-cut turbofan engine in the virtual aerospace hangar.

Objectives:

1. Democratize access to high-risk, high-cost aerospace environments without physical exposure.
2. Enable risk-free operational training on engine start-up, shutdown, and RPM modulation procedures.
3. Enable students to visually and interactively understand the working principles of a jet engine—beyond textbook diagrams.
4. Provide safe, repeatable, and self-paced exploration of engine subsystems without needing physical hardware.

5. Bridge the theory-practice gap by simulating real operational dynamics (e.g., counter-rotating stages, RPM-dependent behaviour).
6. Reduce carbon footprint, and equipment wear associated with physical mock-ups or live engine runs.

Methodology:

The project follows a user-centered design approach, developed in Unity 6000.2.2f1 using the Universal Render Pipeline (URP) for mobile optimization. The core engine model—a half-cut turbofan—is imported as an FBX file from Blender, with each rotating stage (Main Fan, HPC, HPT, LPT) structured as independent child objects to enable individual animation. The XR Interaction Toolkit (v2.5+) and Meta All-in-One SDK (v78) facilitate smooth joystick-based locomotion, ray/poke interaction, and deployment on the Meta Quest 3 headset. A custom C# script manages engine state, RPM-to-rotation mapping (1 RPM = 6°/sec), and directional multipliers (+1 for Main Fan/HPT, –1 for HPC/LPT). The UI uses TextMeshPro for crisp world-space controls (Start/Stop, RPM slider, status display). Additionally, scaled-down interactive prefabs of individual engine parts (e.g., compressor blades) are implemented using XR direct interactors, allowing users to grab, rotate, and inspect them. All assets are optimized for offline use, with static batching and texture compression ensuring stable 72+ FPS performance.

Result and Conclusion:

The final system achieves stable 72–80 FPS on Meta Quest 3 with 100% functional reliability. Users can:

- Start/stop the engine smoothly,
- Adjust RPM with immediate visual feedback,
- Observe correct counterrotation of spools,
- Access part-specific explanations via buttons,
- Pick up, scale, and rotate miniature engine components.

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Future Scope:

The future scope of this project includes:

1. Enable user interaction with all individual miniature engine parts for detailed inspection and manipulation.
2. Implement a snap-together assembly system allowing learners to build a functional small-scale engine from individual components.
3. Integrate a realistic fuel combustion visualization module to illustrate airflow, ignition, and exhaust dynamics in real time.
4. Develop curriculum-aligned interactive exercises based on aerospace syllabus topics to reinforce learning through guided tasks and challenges.