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REIMAGINING HUMAN HABITATION IN LOW EARTH ORBIT: ADAPTIVE DESIGN STRATEGIES FOR FUTURE SPACE STATIONS

Abstract

This paper presents findings from an innovative architectural studio conducted in collaboration with Starlab, focusing on the design of a Low Earth Orbit (LEO) commercial and research station. As space exploration shifts from government-led scientific missions to include commercial ventures with longer-duration stays, the imperative to prioritize human comfort, psychological well-being, and productivity has become paramount. The studio challenged 13 architecture students to design habitable environments for diverse users including astronauts, scientists, engineers, and tourists. The studio employed a comprehensive methodology integrating computational design, iterative modeling, human scale studies, and physical prototyping to explore spatial solutions for microgravity environments. Students progressed through concept studies, leveraging digital tools to generate and refine configurations that would be impossible under Earth's gravitational constraints. 3D modeling and simulation techniques facilitated spatial testing, while physical models validated ergonomic considerations and transformation mechanics. The design research identified three critical design principles essential for successful space habitation: multifunctionality, multidirectionality, and customization. Multifunctionality challenges the conventional approach of dedicating spaces to singular purposes, instead creating adaptable environments that transform to support various activities. One student design featured modular units that attach to perimeter walls and reconfigure using human power to create either expansive spaces for collaborative experiments or subdivided areas for individual work. Another one proposed using human power and resistive training to move spaces and equipment on rails allowing new space to emerge. Multidirectionality exploits the three-dimensional potential of microgravity environments by designing infrastructure, furniture, and equipment accessible from all orientations. Examples include six-sided storage units with each face serving different functions—from laptop workstations to specialized experimental equipment—and sleeping units that double as comfortable lounging chairs when approached from the opposite direction. Customization addresses the diverse physical, psychological, and cultural needs of inhabitants, rejecting standardized "one-size-fits-all" solutions. Student projects explored adjustable sleeping quarters that adapt to different body types and preferences, and modular systems delivering individualized sound, lighting, and temperature conditions—enabling astronauts with different needs to work productively in close proximity. This paper demonstrates how these human-centered design strategies can be integrated into cohesive architectural solutions, balancing technological constraints with adaptability and usability. The findings contribute to the growing discourse on space architecture, offering insights relevant not only for future commercial space stations but also for terrestrial applications where flexibility, efficiency, and personalization are increasingly valued. As humanity moves toward a sustainable long-term presence beyond Earth, rethinking spatial organization in microgravity environments represents a crucial step forward.