Quantum Computing for Aerothermal and Structural

Optimization of Next-Generation Mobility Systems

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***Abstract*—Next-generation mobility systems—ranging from electric vertical takeoff and landing (eVTOL) vehicles to hypersonic aircraft and high-efficiency autonomous drones—require advanced aerothermal and structural optimization techniques to meet demands for safety, performance, and sustainability. Traditional computational approaches, such as finite element analysis, computational fluid dynamics (CFD), and multi-physics simulation, face increasing computational burdens due to the nonlinear interactions among thermal loads, aerodynamic behavior, material deformation, and structural integrity. This study investigates the role of quantum computing in accelerating and improving aerothermal and structural optimization workflows. Leveraging quantum algorithms, including quantum annealing, variational quantum eigensolvers (VQE), quantum approximate optimization algorithms (QAOA), and quantum-inspired multi-objective solvers, the proposed framework enhances the exploration of high-dimensional design spaces and improves the computational efficiency of complex optimization tasks. Early experiments on benchmark aerothermal–structural models demonstrate improved convergence rates, superior Pareto-optimal solutions, and enhanced predictive accuracy compared to classical methods. The findings show that quantum computing has the potential to fundamentally transform mobility system design by enabling faster iteration cycles, better thermal–structural co-optimization, and more energy-efficient architectures suitable for sustainable transportation futures.**

The rapid evolution of next-generation mobility systems has driven a renewed emphasis on advanced optimization techniques that unify thermal, aerodynamic, and structural considerations [3]. Emerging technologies such as eVTOL aircraft, high-speed autonomous drones, long-endurance electric aircraft, and hypersonic systems present unique engineering challenges. These platforms must simultaneously manage aerodynamic stability, structural resilience, thermal loads, material fatigue, and energy efficiency—resulting in design spaces characterized by extreme complexity and nonlinear multi-physics interactions [4]. Traditional computational tools, while robust, increasingly struggle to efficiently explore these domains at the scale and resolution demanded by modern aerospace innovation.

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Aerothermal optimization requires simultaneous modeling of turbulent flow behavior, compressible aerodynamics, heat transfer, and structural deformation under changing flight conditions [1]. Structural optimization, similarly, must account for topology, material distribution, vibration response, crash loads, and manufacturability constraints. The computational cost of coupling CFD, finite element analysis, and multi-physics simulation grows exponentially with

